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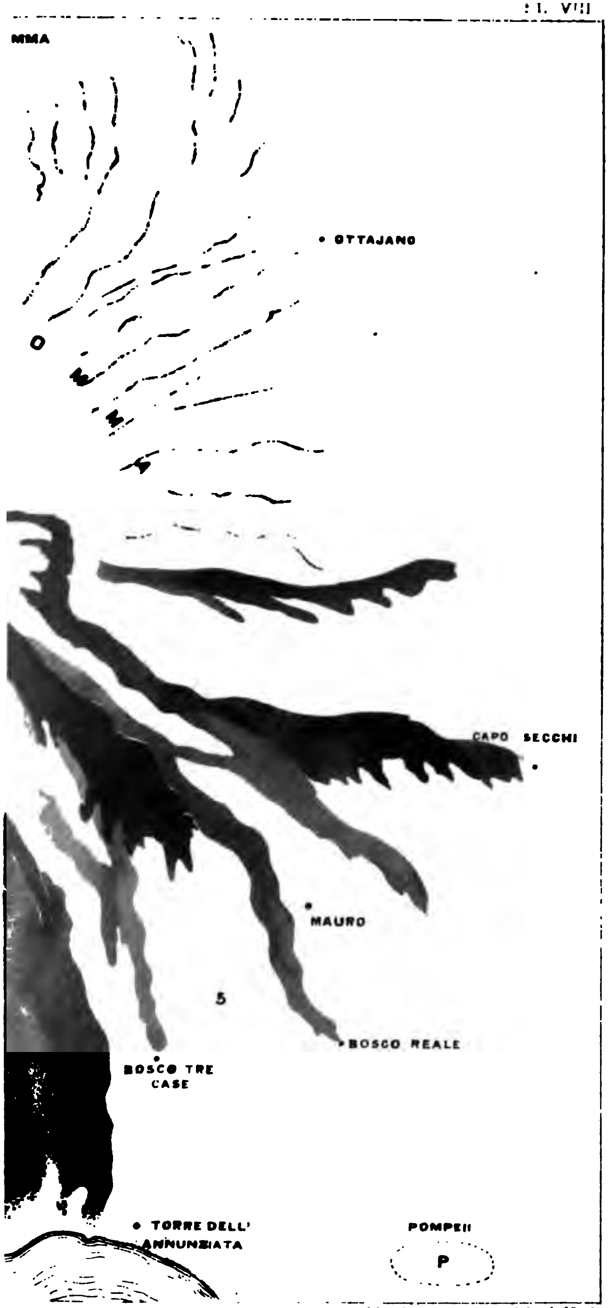

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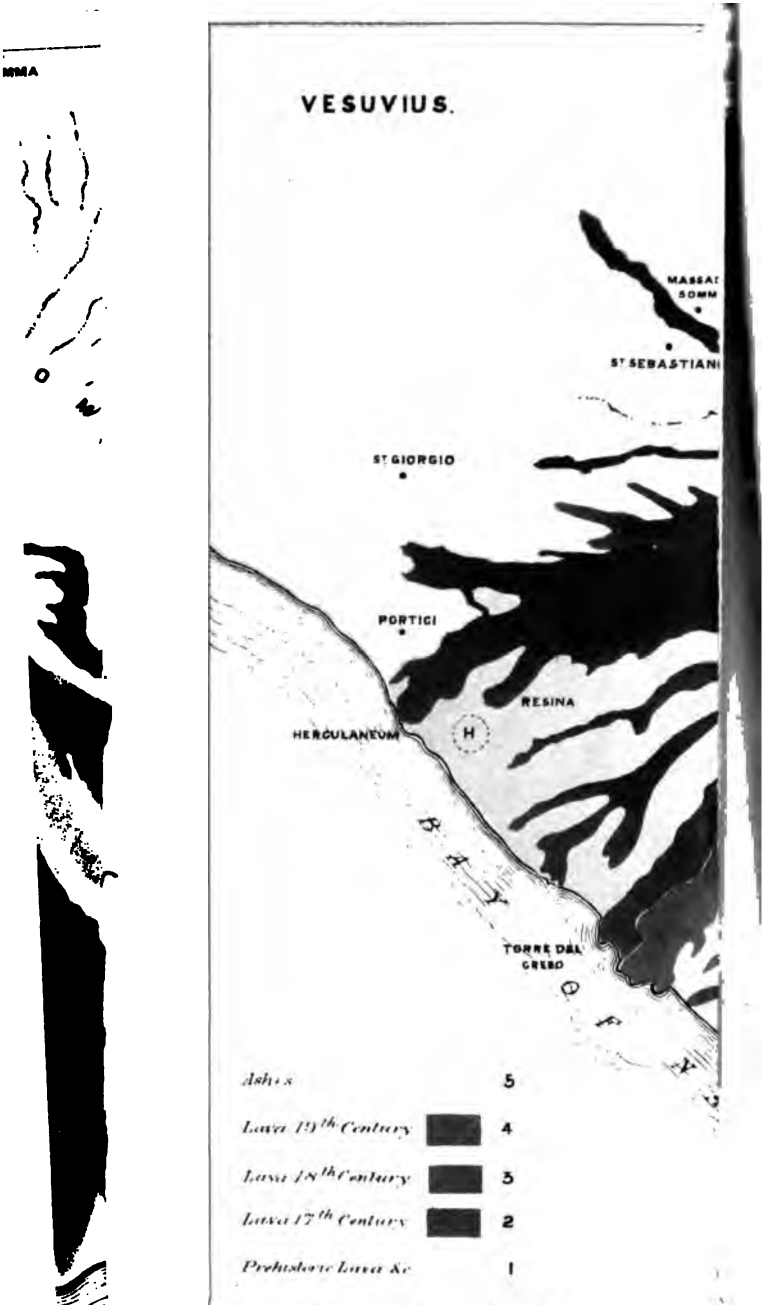

Drawn by Prof. Phillips

VESUVIUS

BY

JOHN PHILLIPS, M. A.

HON. FELLOW OF MAGDALEN COLLEGE, OXFORD;
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Oxford

AT THE CLARENDON PRESS

M DCCC LXIX

TO

THE LADY

WHOSE THOUGHTFUL BENEVOLENCE VISITS

ALIKE THE CHILDREN OF LABOUR AND THE CULTIVATORS

OF ART, LITERATURE, AND SCIENCE,

THE FOUNDER OF

THE BURDETT-COUTTS SCHOLARSHIPS

FOR THE ADVANCEMENT OF GEOLOGY IN

OXFORD,

THIS VOLUME IS GRATEFULLY

DEDICATED.

PREFACE.

About forty years since, I began, at the request of Dr. Daubeny, to compose the article 'Geology' for the 'Encyclopædia Metropolitana,' the portion relating to Volcanos being reserved for himself. As, however, many of the phænomena to be described as volcanic were of great interest in other branches of physical inquiry, and the theory of volcanos could be in no manner separated from the general course of geological reasoning, I took the earliest opportunity of visiting the districts of the Rhine, the Eifel, and Auvergne, so rich in monuments of the older heat-struggles of Nature. It was, however, only in the early part of this present year that the perpetual engagements of a most busy life were so far relaxed as to allow me to visit Vesuvius, fortunately then in action.

Fortunately, also, an early friend and companion in geological exploration, Mr. John Edward Lee, of Caerleon, was able to accompany me, well prepared

to lessen the labour and augment the enjoyment of a diligent search among monuments of art, records of history, and the grandest phænomena of nature.

During our stay in Naples we benefited, as many English geologists and physicists are thankful to acknowledge, by the large geological knowledge and liberal communications of Professor Guiscardi; the ingenious instruments so well employed by Professor Palmieri, in recording the movements of Vesuvius, were explained to us by that able experimentalist; we examined the minerals which Professor Scacchi has made famous, in the Museum of the University; and Mr. Wreford gave to us the cheerful aid which makes a visit to Naples so pleasant to his countrymen.

On my return to Oxford, I was easily induced to give lectures before the University and to the students who attend my class, concerning the facts which had been observed, and the reasonings to which they appeared to lead.

The substance of these lectures is now submitted to the attention of students in geology; who can never be weary of a subject which has been honoured by the special researches of Babbage, Daubeny, Forbes, Lyell, and Scrope; which has interested Davy, and Gay Lussac, Rose, Abich, Delesse, Daubrée, Fouqué, and St. Claire Deville; called forth the theoretical views

of Dufrenoy, De Beaumont, Humboldt, Necker, and Von Buch; and has been submitted to daily scrutiny by Hamilton, Monticelli, Scacchi, Guiscardi, and Palmieri.

My purpose has been first to collect an authentic history of the mountain called Vesuvius, and of its successive eruptions; next, to arrange the main facts and phænomena which have been observed in and around Vesuvius, in a settled order; and finally, to present such thoughts and interpretations as appear to me justly founded on these observations, and in harmony with the working laws of nature.

Of many sketches rapidly made on the spot by my companion and myself, a few have been translated into engravings and lithographs, but the greater number sketched in outline on wood by myself, along with other diagrams which seemed useful for reference. I am indebted to my friend Mr. Lowry, for directing the engraving; Messrs. Newbald and Stead, of York, have executed the colour-printing and lithographs; and Mr. De Wilde has patiently fixed my ideas on wood.

While I am sending these last words to the press, the dying splendours of Vesuvius have been followed by a revival of the fires in his great Sicilian rival; in the course of the year which is expiring we have been terrified by the vast earthquakes and prodigious

lava-floods in the Pacific Sea and along its eastern shores; and tremors in our own Islands, and other parts of Europe, come to support the view which I have gathered from the study of Vesuvius and Ætna (p. 162), that we are now in the midst of a period of more than average struggle with the imprisoned energy of Fire.

OXFORD, *December*, 1868.

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ERRATUM.

Page 189, line 5, *for* Pl. VI. *read* Pl. III.

ILLUSTRATIONS.

CHAPTER I.

VESUVIUS AT REST.

BEFORE A.D. 79.

'Kennst du das Land, wo die Citronen blühn,
Im dunkeln Laub die Gold-Orangen glühn,
Ein sanfter Wind vom blauen Himmel weht,
Die Myrte still, und hoch der Lorbeer steht?'
GOETHE.

THROUGH eighteen centuries the dwellers round the Bay of Naples have watched with mingled pride, wonder and alarm, the great solitary mountain whose shadow in the morning stretched across the sea, and whose evening splendour threw into far distance the snowy peaks of the Apennines.

Well might they be proud of so fair a prospect. All around the mountain, and even climbing to half its height, stretch vineyards and orange-groves, populous towns and prosperous villages, churches, palaces and ports; the well-paved road, and the Strada Ferrata. Here the Norman built his fortress, the Roman reared his amphitheatre; and long before the birth of Rome, the wandering Greek or Phœnician trader laid the foundations of Cumæ and Pæstum, perhaps as long after

an earlier race had built the giant walls of Arpinum and Alatrium, Ferentinum and Venafrum[a].

Such has ever been this fertile land since history began to shed light on ancient Hesperia; a country on which the sun shines in his strength, washed by a translucent sea, bordered by the most picturesque shores in the world, and these crowned by villas and palaces, temples and tombs, of every age and many nations—worshippers of Neptune the earth-shaker, and believers in Januarius, whose very image stays the heaving of the ground, and arrests the current of lava.

Well might they wonder and be terrified! More than fifty times since the Christian æra has the mountain poured forth floods of lava and tossed up clouds of ashes; while far more frequent tremblings of the earth have justified the fable of antiquity, that Titanic forces lay oppressed but struggling below the heavy load of the Phlegræan hills[b]. The 'fortunate Ausonians,' who live amidst these occasional terrors and this perpetual fertility, are sometimes awakened by the groans of the

[a] The names are given in the Latin form. Cumæ, now Cuma (Κοῦμαι, Ptol.; Κύμη, Strab.), was founded by a colony from Chalcis in Eubœa. Pæstum (Ποσειδωνία, Gr.) is of unknown origin; the other cities contain Cyclopæan architecture, and are usually regarded as Pelasgic.

[b] The contest of Earth and Sky, which the Greek fable of Typhœus (Τυφῶν) brings before us, is not only locally associated with volcanic energy in the region round Naples and the greater tract of fire round Ætna, but is traceable in the Catacecaumene and elsewhere in Asia Minor. And in a more general form, which recognises a powerful spirit of evil, it occurs in Egyptian mythology, where Typhon is opposed to Osiris, as Ahriman to Ormuzd in Persian story.

insurgent spirit of fire, and sometimes, with their churches and houses, are overwhelmed by red streams of lava, or buried under dark clouds of ashes. Even the sea which washes the foot of Vesuvius has been invaded by its fiery currents, and vast tracts of surrounding country, and islands dimly seen in the distance, have been thickly covered with its suffocating dust transported by the wind.

The prolific soil which supports the large population on the Vesuvian slopes is the gift of the mountain, derived from lava long since decomposed, or showers of dry ashes, or sediments caused by floods of rain, or rivers of mud which issued from the volcano itself.

More than this, the broad plains of 'Campania the happy,' stretching around from the sea to the mountains, to Nola, to Capua and Gaieta, are based on volcanic accumulations, stratified indeed, and in a great degree formed under the sea, but certainly derived from below, through fiery channels which were situated in or near the great chimney of Vesuvius. Without exaggeration it may be truly said that all this fertile region is the product of the volcano, even as the half-deserted Campagna, which extends round the seven-hilled city, is also in great part composed of sediments derived from the eruptions of the Alban and Ciminian hills. At intervals of years, enormous destruction of men and cities, fields and vineyards; after centuries and decades of centuries, richer inhabitants cultivate more extended lands, with better knowledge how to foretell and interpret, and in some degree to guard against, the recurring agonies of nature.

In the attempt to trace back to the earliest time the history of this struggle of the internal forces against the surface powers of nature, authentic records soon desert us. The first eruption mentioned, in the year A.D. 79, broke upon the Roman philosophers quite as a wonder, and excited to a fatal investigation the curiosity of the elder Pliny. Yet in the Bay of Naples, near Torre del Greco, are portions still visible of lava currents of earlier date, which must have suggested to thoughtful observers the dangerous nature of the ground on which they had built villas and cities.

Looking back from the point of time when Vesuvius became for ever famous, the first passage which strikes in Latin authors is that written by Pliny, only a few years before the outburst of the volcano, with which his end is connected. After noticing Cumæ of the Chalcidensians, Misenum, the port of Baiæ, Bauli, the Lucrine Lake and Avernus—near which was once the Cimmerian town — the colony of Puteoli, formerly Dicæarchia, the Phlegræan fields and Acherusian marsh, near Cumæ; he adds, 'Litore autem hoc Neapolis, Chalcidensium et ipsa, Parthenope a tumulo Sirenis appellata: Herculanium, Pompeii; haud procul spectante monte Vesuvio, alluente vero Sarno amne [c].'

In this author no mention occurs of Vesuvius in relation to earthquakes or volcanic fire; but he has preserved a curious tradition of the occurrence of lightning in winter and summer in the southern parts of Italy, such not being the case elsewhere :—'Italiæ

[c] Nat. Hist. iii. 5, Aldine Ed.

quoque partibus iis, quæ a septentrione discedunt ad teporem, qualis est Urbis et Campaniæ tractus, juxta hyeme et æstate fulgurat, quod non in alio situ [d].'

The penetrating glance of Seneca (B.C. 1 to A.D. 64) had detected the true character of Vesuvius, which had thrown out more than its own mass of earthy matter, being in fact a channel for the fire, but not its food:—'in ipso monte non alimentum habet sed viam [e].'

Still earlier, the accurate geographer Strabo (about B.C. 30) had observed the rich cultivation of the Vesuvian slopes except at the summit (πλὴν τῆς κορυφῆς), which was for the most part flat, and quite barren; and remarking the cindery aspect, and cavernous rocks, as if eaten by fire, conjectured that in ancient times the country was all in a state of burning, being full of fiery cavities, though now extinct for want of fuel. And he adds, 'perhaps this is the cause of the fertility [f].'

Vitruvius also, the celebrated architect in the days of Augustus, when speaking of the 'pulvis Puteolanus,' now called pozzolana, near Naples, which he supposes to have been formed by heat, notices a tradition that Vesuvius also in former times emitted fire. 'Non minus etiam memoratur antiquitus crevisse ardores et abundasse sub Vesuvio monte et inde evomuisse circa agros flammas [g].'

[d] Nat. Hist. ii. 50, Aldine Ed. [e] Letter 79.

[f] Strabo, Geog. Book v. For this and some other passages in the original language, see the Appendix.

[g] Lib. ii. cap. vi.

And Tacitus, mentioning the eruption of Vesuvius in the reign of Titus, seems to hint likewise at former eruptions, in these words: 'Jam vero Italia novis cladibus, vel post longam sæculorum seriem repetitis afflicta. Haustæ aut obrutæ urbes fœcundissimâ Campaniæ orâ[h].'

Diodorus Siculus takes us back to B.C. 45, and gives us the picture of Vesuvius as it appeared to a native of Sicily born within sight of Ætna. 'The whole region was named Phlegræan, from the culminating point, which is now called Οὐεσούϊος, bearing many indications of having emitted fires in ancient time[i].'

One more vista, of earlier date (B.C. 72), shows us the gallant swordsman, the gladiator Spartacus, stung by the intolerable wrongs of the Roman Government, retreating for shelter to the very summit of Vesuvius, in the midst of wild vines, which with their twisted branches gave him the means of escaping down the steep crater-walls, and of surprising his besieger, the negligent Clodius Glabrus. 'Prima velut arena viris Mons Vesuvius placuit. Ibi cum obsidarentur a Clodio Glabro, per fauces cavi montis vitineis delapsi vinculis, ad imas ejus descendere radices; et exitu invio, nihil tale opinantis ducis, subito impetu castra rapuere[k].'

The story is given with amplifications by Plutarch,

[h] Tac. Hist. lib. i. cap. 2. The passage is here given according to Lipsius' note. Hamilton, Letter V. Daubeny, Volcanos, ed. ii. p. 217. In this work most of the authorities referring to the history of Vesuvius were first collected.

[i] Lib. iv. c. 21.

[k] Florus, lib. iii. c. 20. Conf. Velleius Paterculus, Plutarch.

in his Life of Crassus. 'Clodius the Prætor, with three thousand men, besieged them in a mountain having but one narrow and difficult passage, which Clodius kept guarded; all the rest was encompassed with broken and slippery precipices, but upon the top grew a great many wild vines: they cut down as many of their boughs as they had need of, and twisted them into ladders long enough to reach from thence to the bottom, by which, without any danger, all got down save one, who stayed behind to throw them their arms, after which he saved himself with the rest.' 'On the top' must here be interpreted as the summit of the exterior slope.

Here, less than a century before the birth of Christ, the real history of Vesuvius begins, and in the present mountain we see the object of Roman and far earlier observation, perhaps veneration, only masked by the accumulations of later days.

As far as can be discovered, Vesuvius—Vesevus, Vesvius, or Vesbius—is the oldest historical name of the mountain. It is sometimes used adjectively, as by Virgil, when speaking of fertile soil:—

'Illa ferax oleo est; illam experiêre colendo
Et facilem pecori, et patientem vomeris unci.
Talem dives arat Capua, et vicina Vesevo
Ora jugo, et vacuis Clanius non æquus Acerris[1].'

Strabo calls it ὄρος τὸ Οὐεσουΐου, and Diodorus Siculus ὁ τόπος Οὐεσουΐος, the adjectival form in the Greek corresponding to that in the Latin.

[1] Georg. ii. 222-225.

There is some tradition for the use of the title of the obscure old god, 'Summanus,' perhaps a synonym of Pluto, since to him was ascribed lightning that happened by night, as to Jove what occurred in daylight, as Pliny tells us: 'Thuscorum literæ novem deos emittere fulmina existimant, eaque esse undecim generum, Jovem enim trina jaculari. Romani duo tantum ex iis servavere: diurna attribuentes Jovi, nocturna Summano [m].' He was worshipped as an unknown deity, a ruler of night and shadows, fit to haunt the dreary top of an old volcano. Ovid informs us that temples were reared in his honour, in an earlier age of Rome:—

> 'Reddita, quisquis is est, Summano templa feruntur,
> Tum, cum Romanis Pyrrhus timendus erat [n].'

If the name of Monte Somma, the north-eastern half of Vesuvius, be derived from Mons Summanus, perhaps we may add the supposition of a temple in honour of the god, somewhere near the hermitage or the cross of San Salvatore.

The records of Vesuvius conduct us through less than twenty centuries, half the age of the temples of Egypt, but etymology has striven to extend the annals. Phœnician or Syriac roots have been found or supposed for Vesuvius, Somma, Herculaneum, Pompeii, and Stabiæ, which might indicate in the earliest colonists a knowledge of the volcanic character of the country. If we suppose the name of Vesuvius to have been imposed by early Greek settlers, ΣΒΕ, the radical of several words

m Nat. Hist. ii. 52. n Fasti, vi. 731.

implying extinction, offers itself for adoption[o]. In this case the prefix being taken as negative, the meaning of the word is 'unextinguished;' and it would lead us to accept as probable some knowledge or tradition of habitual or frequent eruptions in prehistoric times. If, on the other hand, a Phœnician origin be preferred, and Vo—Seveev—the place of fire, be thought probable, the same conclusion as to the fact of very ancient knowledge of earlier volcanic violence may be maintained[p].

Thus we proceed rather dimly through another period of a thousand or perhaps two thousand years, and find at the beginning of them a volcanic region much like what we see before us, tempting for settlers, and colonized by Phœnicians, Pelasgians, and Greeks.

To voyagers like these, the phænomena of Ætna and Stromboli must have been familiar, and the volcanic character of the country round Naples could not have been indifferent. Perhaps they saw the Solfatara in action; almost certainly they enjoyed the hot baths by the Avernian Lake; and we may ascribe to them the traditional superstition concerning it, which gave occasion to the well-known lines of Lucretius, in which it is taken for granted that Avernus is the Hesperian form of Ἄορνος:—

> 'Nunc age, Averna tibi quæ sint loca cumque lacusque,
> Expediam: quali naturâ prædita constent.

[o] Liddell and Scott—Pott. Etym. Forsch. i. 87.

[p] See this, and other attempts of the kind by Neapolitan authors, collected in Murray's Handbook for Naples.

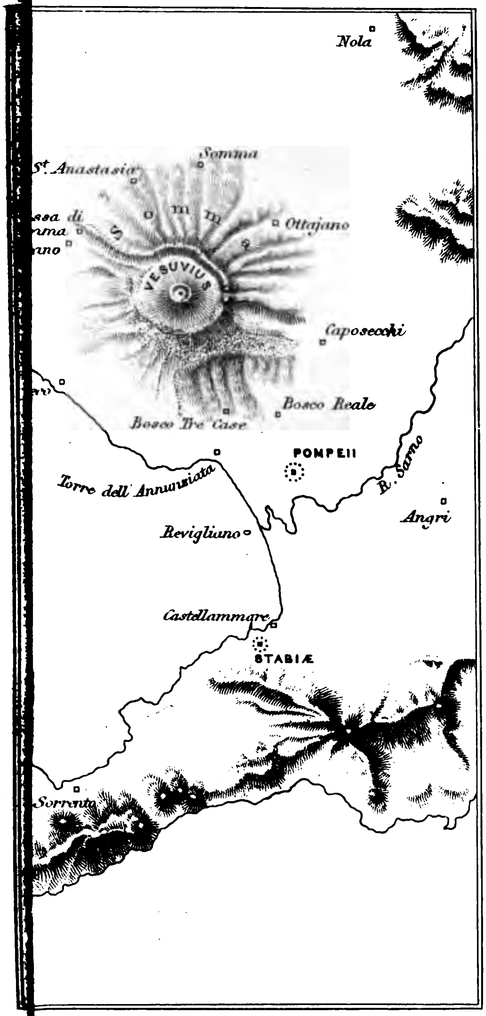
Principio, quod Averna vocantur nomine, id ab re
Inpositum est, quia sunt avibus contraria cunctis,
E regione ea quod loca quom venere volantes,
Remigii oblitæ, pennarum vela remittunt,
Præcipitesque cadunt, molli cervice profusæ,
In terram, si forte ita fert natura locorum;
Aut in aquam, si forte lacus substratus Averni.
Is locus est Cumas apud; acri sulphure montes
Obpleti calidis ubi fumant fontibus aucti [q].'

The allusion in the concluding lines is probably to the Solfatara, but may be to Agnano, both anciently in the territory of Cumæ and its dependencies, and both yielding sulphureous vapours near their margins.

In whatever degree, however, the appearances of former convulsion about Vesuvius and the Solfatara, Avernus and Agnano, may have interested the philosophers and poets of Greece and Rome, still, for the people at large, Campania was, as Pliny expresses it, truly a happy region, the triumphant work of rejoicing nature, where Bacchus and Ceres met in friendly rivalry to augment the means of human enjoyment. The long voluptuous dream came to a startling end.

[q] De Rerum Naturâ, vi. 739.

PL. I.



Nola
Somma
St. Anastasia
Ottajano
VESUVIUS
Caposecchi
Bosco Reale
Bosco Tre Case
POMPEII
R. Sarno
Torre dell' Annunziata
Angri
Reviglìano
Castellammare
STABIÆ
Sorrento

CHAPTER II.

VESUVIUS IN ACTION.

DESTRUCTION OF POMPEII AND HERCULANEUM.

A.D. 79.

'Hæc Veneris sedes, Lacedæmone gratior illi.
Hic locus Herculeo nomine clarus erat,
Cuncta jacent flammis et tristi mersa favillâ.'
MARTIAL.

No dread of eruptions, and little thought of malaria, disturbed the Hesperian colonists through many ages of material prosperity. They remembered, no doubt, as other men,—

'That e'en beneath the myrtle shade
Disease, and pain, and death invade;'

but when they climbed the Vesuvian cone, and saw it, as now, bare at the summit, and rich in every variety of beauty at the base, they beheld no black coils of barren lava, no deserts of unfruitful ashes, spread over broad tracts once rich with an earlier cultivation, and gathered no idea of approaching disaster. The first note of alarm was given by the earthquake—sure forerunner of subaërial volcanic excitement—itself the deep-seated symptom of the same disease. Earthquakes of

great violence, beginning (or at least first recorded) sixty-three years after the birth of Christ, disturbed all Campania, and shattered the cities of Pompeii and Herculaneum. In the former place the temple of Isis was so much damaged as to require reconstruction—a public duty, which was, however, performed by a private citizen, at his own expense. An inscription now visible over the entrance records an act of municipal gratitude to the liberal restorer of the sacred edifice:—

N . POPIDIVS . N . F . CELSINVS.
ÆDEM . ISIDIS . TERRÆ . MOTV . CONLAPSAM.
A . FVNDAMENTIS . P . SVA . RESTITVIT.
HVNC . DECVRIONES . OB . LIBERALITATEM.
CVM . ESSET . ANNORVM . SEXS . ORDINI . SVO.
GRATIS . ADLEGERVNT.

Suetonius has preserved incidentally a notice of this earthquake in connection with the 'first appearance' of Nero on the stage at Naples. This singular 'master of the world' loitered and amused himself much in the city of the Syren, and amid the waters of Baiæ. To be singing when Vesuvius was thundering, and to be fiddling while Rome was burning, was not unfitting the imperial madcap. 'Et prodiit Neapoli primum, ac ne, concusso quidem repente motu terræ theatro, ante cantare destitit, quam inchoatum absolveret *νόμον*. Ibidem sæpius et per complures cantavit dies.'

For sixteen years these earth-shakings continued. At length, on the night of August 24, A.D. 79, they became extremely violent, making the whole country reel and

totter. Then came the eruption, which the letters of Pliny the younger have made famous as the cause of his uncle's death. The main physical feature of this remarkable event was an immense discharge of ashes, rising in black clouds above the mountain, and carrying a terrible shadow over the whole sea and land as far as Capreæ, and beyond Misenum. When the gloom was at last relieved, Vesuvius was seen to be the focus of the eruption, which, it appears by modern research, had caused the ruin of the whole south-western part of the mountain, without perhaps rearing a new cone, to represent the modern Vesuvius, in the centre of the old depressed crateral plain of Somma.

Pliny the younger, to whom we are indebted for the only contemporary account of this great convulsion, was at the time of its occurrence resident with his mother at Misenum, where the Roman fleet lay, under the command of his uncle, the great author of the 'Historia Naturalis.' His account, contained in two letters to Tacitus (lib. vi. 16, 20), is not so much a narrative of the eruption, as a record of his uncle's singular death. The translation which follows is adopted from the very free version of Melmoth, except in one or two places, where it differs much from the ordinary text. The letters are given entire, though some parts are merely specimens of style.

'Your request that I would send you an account of my uncle's death, in order to transmit a more exact relation of it to posterity, deserves my acknowledgments; for if this accident shall be celebrated by your

pen, the glory of it, I am assured, will be rendered for ever illustrious. And, notwithstanding he perished by a misfortune which, as it involved at the same time a most beautiful country in ruins, and destroyed so many populous cities, seems to promise him an everlasting remembrance; notwithstanding he has himself composed many and lasting works,—yet I am persuaded the mentioning of him in your immortal works will greatly contribute to eternize his name. Happy I esteem those to be, whom Providence has distinguished with the abilities either of doing such actions as are worthy of being related, or of relating them in a manner worthy of being read; but doubly happy are they who are blessed with both these uncommon talents; in the number of which my uncle, as his own writings and your history will prove, may justly be ranked. It is with extreme willingness, therefore, I execute your commands; and should, indeed, have claimed the task if you had not enjoined it.

'He was at that time with the fleet under his command at Misenum. On the 24th of August [nonum calend. Septembres], about one in the afternoon [hora fere septima], my mother desired him to observe a cloud which appeared of a very unusual size and shape. He had just returned from taking the benefit of the sun, and after bathing himself in cold water, and taking a slight repast, was retired to his study. He immediately arose, and went out upon an eminence, from whence he might more distinctly view this very uncommon appearance. It was not at that distance dis-

cernible from what mountain this cloud issued, but it was found afterwards to ascend from Mount Vesuvius. I cannot give a more exact description of its figure than by resembling it to that of a pine-tree, for it shot up to a great height in the form of a trunk, which extended itself at the top into a sort of branches, occasioned, I imagine, either by a sudden gust of air that impelled it, the force of which decreased as it advanced upwards, or the cloud itself being pressed back again by its own weight, expanded in this manner: it appeared sometimes bright, and sometimes dark and spotted, as it was more or less impregnated with earth and cinders. This extraordinary phænomenon excited my uncle's philosophical curiosity to take a nearer view of it. He ordered a light vessel [liburnicam] to be got ready, and gave me the liberty, if I thought proper, to attend him. I rather chose to continue my studies, for as it happened, he had given me an employment of that kind. As he was passing out of the house he received despatches [codicillos]: the marines at Retina, terrified at the imminent peril (for the place lay beneath the mountain, and there was no retreat but by ships), intreated his aid in this extremity [a]. He accordingly changed his first design, and what he began with a philosophical he pursued with an heroical turn of mind.

[a] This sentence is not taken from Melmoth. The ordinary text is: 'Egrediebatur domo, accipit codicillos. Retinæ classiarii imminenti periculo exterriti (nam villa ea subjiciebat, nec ulla nisi navibus fuga), ut se tanto discrimini eriperet, orabant.' Melmoth, using another text, says,—'As he was coming out of the house, he received a note from Rectina, the wife of Bassus, who was in the utmost alarm

He ordered the galleys [quadriremes] to put to sea, and went himself on board with an intention of assisting not only Retina but many other places, for the population is thick on that beautiful coast. When hastening to the place from whence others fled with the utmost terror, he steered his direct course to the point of danger, and with so much calmness and presence of mind, as to be able to make and dictate his observations upon the motion and figure of that dreadful scene. He was now so nigh the mountain, that the cinders, which grew thicker and hotter the nearer he approached, fell into the ships, together with pumice stones, and black pieces of burning rock; they were likewise in danger, not only of being aground by the sudden retreat of the sea, but also from the vast fragments which rolled down from the mountain, and obstructed all the shore [jam vadum subitum, ruinaque montis littora obstantia].

'Here he stopped to consider whether he should return back again; to which the pilot advising him, "Fortune," said he, "favours the brave; carry me to Pomponianus." Pomponianus was then at Stabiæ, separated by a gulf, which the sea, after several insensible windings, forms upon the shore. He [Pomponianus] had already sent his baggage on board; for though he was not at that time in actual danger, yet

at the imminent danger which threatened her; for her villa being situated at the foot of Mount Vesuvius, there was no way to escape but by sea; she earnestly entreated him, therefore, to come to her assistance.' The 'classiarii' were, clearly, not sailors.

being within view of it, and indeed extremely near, if it should in the least increase, he was determined to put to sea as soon as the wind should change. It was favourable, however, for carrying my uncle to Pomponianus, whom he found in the greatest consternation. He embraced him with tenderness, encouraging and exhorting him to keep up his spirits; and the more to dissipate his fears he ordered, with an air of unconcern, the baths to be got ready: when, after having bathed, he sat down to supper with great cheerfulness, or at least (what is equally heroic) with all the appearance of it.

'In the meantime, the eruption from Mount Vesuvius flamed out in several places with much violence, which the darkness of the night contributed to render still more visible and dreadful. But my uncle, in order to soothe the apprehensions of his friend, assured him it was only the burning of the villages, which the country people had abandoned to the flames; after this he retired to rest, and it is most certain he was so little discomposed as to fall into a deep sleep; for being pretty fat, and breathing hard, those who attended without actually heard him snore. The court which led to his apartment being now almost filled with stones and ashes, if he had continued there any time longer, it would have been impossible for him to have made his way out; it was thought proper, therefore, to awaken him. He got up and went to Pomponianus and the rest of his company, who were not unconcerned enough to think of going to bed. They consulted together

whether it would be most prudent to trust to the houses, which now shook from side to side with frequent and violent concussions; or to fly to the open fields, where the calcined stones and cinders, though light indeed, yet fell in large showers and threatened destruction. In this distress they resolved for the fields as the less dangerous situation of the two—a resolution which, while the rest of the company were hurried into by their fears, my uncle embraced upon cool and deliberate consideration.

'They went out, then, having pillows tied upon their heads with napkins; and this was their whole defence against the storm of stones that fell around them. It was now day everywhere else, but there a deeper darkness prevailed than in the most obscure night; which, however, was in some degree dissipated by torches and other lights of various kinds. They thought proper to go down further upon the shore, to observe if they might safely put out to sea; but they found the waves still run extremely high and boisterous. There my uncle, having drunk a draught or two of cold water, threw himself down upon a cloth which was spread for him, when immediately the flames, and a strong smell of sulphur which was the forerunner of them, dispersed the rest of the company, and obliged him to rise. He raised himself up with the assistance of two of his servants, and instantly fell down dead, suffocated, as I conjecture, by some gross and noxious vapour, having always had weak lungs, and being frequently subject to a difficulty of breathing.

'As soon as it was light again, which was not till the third day after this melancholy accident [Ubi dies redditus, is ab eo quem novissime viderat tertius], his body was found entire, and without any marks of violence upon it, exactly in the same posture that he fell, and looking more like a man asleep than dead. During all this time my mother and I were at Misenum.—But as this has no connexion with your history, so your inquiry went no farther than concerning my uncle's death; with that, therefore, I will put an end to my letter. Suffer me only to add, that I have faithfully related to you what I was either an eye-witness of myself, or received immediately after the accident happened, and before there was time to vary the truth. You will choose out of this narrative such circumstances as shall be most suitable to your purpose: for there is a great difference between what is proper for a letter and a history; between writing to a friend, and writing to the public. Farewell.'

In this account, which was drawn up some years after the event, from the recollections of a student eighteen years of age[b], we recognise the continual earthquakes; the agitated sea with its uplifted bed; the flames and vapours of an ordinary eruption, probably attended by lava as well as ashes. But it seems likely that the author's memory, or rather the information communicated to him regarding the closing scene of Pliny's

[b] The invitation of his uncle, who offered him a berth in his galley, was declined by the young man, clearly no student of physical science: 'Respondi, studere me velle; et forte ipse quod scriberem dederat.'

life, was defective. Flames and sulphurous vapours could hardly be actually present at Stabiæ, ten miles from the centre of the eruption.

That lava flowed at all from Vesuvius on this occasion has been usually denied: chiefly because at Pompeii and Herculaneum the causes of destruction were different—ashes overwhelmed the former, mud concreted over the latter. We observed, indeed, phænomena on the shore near Torre del Greco which seemed to require the belief that currents of lava had been solidified there at some period before the construction of certain walls, and floors, and other works of Roman date.

In the Oxford Museum, among the specimens of lava to which the dates are assigned, is one referred to A.D. 79, but there is no mode of proving it to have belonged to the eruption of that date.

A second letter from Pliny to Tacitus (Epist. 20) was required to satisfy the curiosity of that historian; especially as regards the events which happened under the eyes of his friend. Here it is, according to Melmoth:—

'The letter which, in compliance with your request, I wrote to you concerning the death of my uncle, has raised, it seems, your curiosity to know what terrors and dangers attended me while I continued at Misenum: for there, I think, the account in my former letter broke off.

"Though my shocked soul recoils, my tongue shall tell."

'My uncle having left us, I pursued the studies which

prevented my going with him till it was time to bathe. After which I went to supper, and from thence to bed, where my sleep was greatly broken and disturbed. There had been, for many days before, some shocks of an earthquake, which the less surprised us as they are extremely frequent in Campania; but they were so particularly violent that night, that they not only shook everything about us, but seemed, indeed, to threaten total destruction. My mother flew to my chamber, where she found me rising in order to awaken her. We went out into a small court belonging to the house, which separated the sea from the buildings. As I was at that time but eighteen years of age, I know not whether I should call my behaviour, in this dangerous juncture, courage or rashness: but I took up Livy, and amused myself with turning over that author, and even making extracts from him, as if all about me had been in full security. While we were in this posture, a friend of my uncle's, who was just come from Spain to pay him a visit, joined us; and observing me sitting with my mother with a book in my hand, greatly condemned her calmness at the same time that he reproved me for my careless security. Nevertheless, I still went on with my author.

'Though it was now morning, the light was exceedingly faint and languid; the buildings all around us tottered; and though we stood upon open ground, yet as the place was narrow and confined, there was no remaining there without certain and great danger: we therefore resolved to quit the town. The people

followed us in the utmost consternation; and as to a mind distracted with terror every suggestion seems more prudent than its own, pressed in great crowds about us in our way out.

'Being got at a convenient distance from the houses, we stood still, in the midst of a most dangerous and dreadful scene. The chariots which we had ordered to be drawn out were so agitated backwards and forwards, though upon the most level ground, that we could not keep them steady, even by supporting them with large stones. The sea seemed to roll back upon itself, and to be driven from its banks by the convulsive motion of the earth: it is certain at least the shore was considerably enlarged, and many sea animals were left upon it. On the other side a black and dreadful cloud, bursting with an igneous serpentine vapour, darted out a long train of fire, resembling flashes of lightning, but much larger. Upon this our Spanish friend, whom I mentioned above, addressing himself to my mother and me with great warmth and earnestness; "If your brother and your uncle," said he, "is safe, he certainly wishes you to be so too; but if he perished, it was his desire, no doubt, that you might both survive him: why therefore do you delay your escape a moment?" We could never think of our own safety, we said, while we were uncertain of his. Hereupon our friend left us, and withdrew with the utmost precipitation. Soon afterward, the cloud seemed to descend, and cover the whole ocean; as it certainly did the island of Capreæ, and the promontory of Misenum. My mother strongly

conjured me to make my escape at any rate, which, as I was young, I might easily do; as for herself, she said, her age and corpulency rendered all attempts of that sort impossible. However, she would willingly meet death, if she could have the satisfaction of seeing that she was not the occasion of mine. But I absolutely refused to leave her, and taking her by the hand, I led her on; she complied with great reluctance, and not without many reproaches to herself for retarding my flight.

'The ashes now began to fall upon us, though in no great quantity. I turned my head, and observed behind us a thick smoke, which came rolling after us like a torrent. I proposed, while we yet had any light, to turn out of the high road, lest she should be pressed to death in the dark by the crowd that followed us. We had scarce stepped out of the path, when darkness overspread us, not like that of a cloudy night, or when there is no moon, but of a room when it is shut up and all the lights extinct. Nothing then was to be heard but the shrieks of women, the screams of children, and the cries of men; some calling for their children, others for their parents, others for their husbands, and only distinguishing each other by their voices; one lamenting his own fate, another that of his family; some wishing to die from the very fear of dying; some lifting their hands to the gods; but the greater part imagining that the last and eternal night was come, which was to destroy the gods and the world together. Among them were some who augmented the real terrors by imaginary

ones, and made the frighted multitude falsely believe that Misenum was actually in flames.

'At length a glimmering light appeared, which we imagined to be rather the forerunner of an approaching burst of flames, as in truth it was, than the return of day. However, the fire fell at a distance from us; then again we were immersed in thick darkness, and a heavy shower of ashes rained upon us, which we were obliged every now and then to shake off, otherwise we should have been crushed and buried in the heap.

'I might boast that, during all this scene of horror, not a sigh or expression of fear escaped from me, had not my support been founded in that miserable, though strong consolation, that all mankind were involved in the same calamity, and that I imagined I was perishing with the world itself! At last this dreadful darkness was dissipated by degrees, like a cloud of smoke; the real day returned, and soon the sun appeared, though very faintly, and as when an eclipse is coming on. Every object that presented itself to our eyes (which were extremely weakened) seemed changed, being covered over with white ashes, as with a deep snow. We returned to Misenum, where we refreshed ourselves as well as we could, and passed an anxious night between hope and fear: though indeed with a much larger share of the latter; for the earthquake still continued, while several enthusiastic people [lymphati] ran up and down, heightening their own and their friends' calamities by terrible predictions. However, my mother and I, notwithstanding the danger we had passed, and that which

still threatened us, had no thoughts of leaving the place till we should receive some account from my uncle.

'And now you will read this narrative without any view of inserting it in your history, of which it is by no means worthy; and indeed, you must impute it to your own request if it shall [not even] deserve the trouble of a letter. Farewell!'

In this narrative, full as it is of the personal feelings and fancies of the young philosopher, it is remarkable that he does not permit his pen to deviate into such important hearsay as that which must have met him at every turn — the destruction of Herculaneum and Pompeii, and other places of less note on the populous coast (erat enim frequens amœnitas loci). Stabiæ and Misenum are described as both and equally covered with suffocating ashes, and threatened by flames; but the former must have been known to have been overwhelmed, the latter only exposed to temporary inconvenience and distress. Nor is this reticence entirely balanced by the garrulity of any other writer, Roman or Greek.

Martial indeed, writing only a few years later than the event, has preserved the memory of the unfortunate towns:—

'Hic est pampineis viridis modo Vesvius umbris,
  Presserat hic madidos nobilis uva lacus;
Hæc juga, quam Nisæ colles, plus Bacchus amavit,
  Hoc nuper Satyri monte dedere choros;
Hæc Veneris sedes, Lacedæmone gratior illi;
  Hic locus Herculeo nomine clarus erat:
Cuncta jacent flammis, et tristi mersa favilla,
  Nec superi vellent hoc licuisse sibi.'

Dion Cassius, writing about A.D. 230—after a century and a half had spread other clouds than its own over the history of Vesuvius—presents us with some floating traditions regarding the great eruption, which he had collected during his residence in Campania. After describing the actual appearance of the mountain, he goes on to say:—

'Such is Vesuvius, and these things take place in it almost every year. But all eruptions which have happened since, though they may have appeared unusually great to those even who have been accustomed to such sights, would be trifling, even if collected into one, when compared to what occurred at the time of which we speak. Many huge men, surpassing human stature, such as the giants are described to have been, appeared wandering in the air and upon the earth, at one time frequenting the mountain, at another the fields and cities in its neighbourhood. Afterwards came great droughts and violent earthquakes, so that the whole plain boiled and bubbled, and the hills leaped, and there were noises underground like thunder, and above ground like roaring, and the sea made a noise, and the heavens sounded, and then suddenly a mighty crash was heard, as if the mountains were coming together, and first great stones were thrown up to the very summits, then mighty fires and immense smoke, so that the whole air was overshadowed, and the sun entirely hidden as in an eclipse.

'Thus day was turned into night, and light into darkness, and some thought the giants were rising again,

(for many phantoms of them were seen in the smoke, and a blast, as if of trumpets, was heard,) while others believed that the earth was to return to chaos, or to be consumed by fire. Therefore men fled, some from the houses out into the ways, others that were without into their houses; some quitted the land for the sea, some the sea for the land, being confounded in mind, and thinking every place at a distance safer than where they were. Meanwhile an inexpressible quantity of dust was blown out, and filled land, sea, and air: which did much other mischief to men, fields, and cattle, and destroyed all the birds, and fishes, and besides buried two entire cities, Herculaneum and Pompeii, while the population was sitting in the theatre. For this dust was so abundant, that it reached Africa, Syria, and Egypt, and filled the air above Rome, and over-clouded the sun; which caused much fear for many days, men neither knowing nor being able to conjecture what had happened. But they thought that everything was to be thrown into confusion, the sun to fall extinguished to the earth, the earth to rise to the sky. At the time, however, these ashes did them no harm, but subsequently they produced a pestilential disease [c].'

Here we have, in a wild mixture of fable and tradition, such as the better age of Pliny would have scorned, the direct though brief statement of the destruction of two ancient and populous cities, which had stood for a thousand years without apprehension of danger.

[c] Dion. Cass. lib. lxvi. This elegant version is taken from the very useful work, entitled Pompeii, U. K. S. vol. i. p. 16.

Even this credulous and imaginative author, however, makes no mention of Stabiæ, which was evidently a considerable port in a fertile territory.

Stabiæ was a town of importance till it was destroyed by Lucius Sulla in the civil war. Strabo does not mention it among towns on the coast. Pliny, Nat. Hist. lib. vii. 15, records its fate, as above stated, and adds that only scattered villages or villas occupied its site. It seems to have been remarkable for a cold acidulated medicinal water [d], and was famous for healthy springs and wholesome milk, and patients used to resort to it to drink the same [e]. Castellammare, which stands, at least in part, upon the ruins of Stabiæ, is still famous for its mineral waters and its fine refreshing climate—cool in a warm region. There are many springs, and, as usual in such a case, they have various qualities, chalybeate, carbonated, and sulphuretted, as at Harrogate.

Some amusement was also found in fishing, as we learn from Plin. Nat. Hist. xxxii. 2, who says of some fishes called melanuri (black-tails): 'In the Stabian district of Campania, at the rock of Hercules, melanuri eagerly take bread thrown into the sea, but will not approach a hook however well baited.'

This place, ten miles from Vesuvius, was overwhelmed with dry ashes, and lapilli, of which the largest, seen by Sir W. Hamilton, weighed less than one ounce. It was partially re-occupied.

[d] Plin. Nat. Hist. xxxi. 2.

[e] Symm. Ep. vi. 17 (18), and Columella, lib. xv. 133:—

'Fontibus et Stabiæ celebres et Vesvia rura.'

A few traces of the old town have been recovered, and some fragments of ancient sculpture, stucco paintings, and papyri were obtained, but the excavations have not been prosecuted since the latter part of the last century.

Pompeii, to which we now turn, has a name of dubious birth. Supposing it to be of Greek origin, the word πομπή, with its congeners, suggests itself; and Solinus (third century) bids us to adopt this, in allusion to processions which he says accompanied the celebration of the victories of Hercules when his fleet was at the mouth of the Sarnus. If this be not accepted, let the Phœnicians have their hearing, for whom ingenious etymology has advanced the claim of the roots Pum Peeah, 'mouth of burning furnace;' and geology helps the 'contention' by affirming that the city was built on a volcanic mound.

Pompeii has a history, short indeed, but of an exciting character. Strabo tells us that, like Herculaneum, it was first held by the Oscans, then occupied by Etruscans and Pelasgians, who were followed by the Samnites; these in their turn expelled by the Romans [f]. Forced at first into the Cumæan league, which probably embraced the whole Bay of Naples, and afterwards transferred to the victorious Etruscans, it became at length a turbulent municipality of the great republic which had spread itself on every side from the conquering city on the Tiber. Situated in a very fertile region, it was the trading port for the inland cities of Nola, Nuceria, and

[f] Strabo, Geography, lib. v.

Acerræ, and imported and exported for these flourishing places through many ages, by means of a navigable river, the Sarno, which is now a mere brook, occasionally swollen to a torrent. If not actually on the sea-shore at the mouth of the river, it must have been nearer to it than now, for the sea-bed has been raised by volcanic agency so as to leave dry a broad tract between Pompeii and the sea; in fact sea-shells and sea-sand are stated to have been found in the almost flat space between the city and the sea. At some early time the sea undoubtedly washed the base of the low mound on which Pompeii was built, and it is most probable that this was the case in historic time, for surely here, as at Herculaneum, and Stabiæ, and Puteoli, the ancient maritime people who established their colony on the Sarno would secure for it an available frontage to the sea. It may be some confirmation of this that rings by which vessels might be moored are said to have been found near the 'sea-gate.' It is also stated that flights of steps have been found at Pompeii, such as must have led down to the water's edge. And Sir C. Lyell[g], in his remarks on this, observes that the lowest of them are said to be still on a level with the sea; from which it may perhaps be concluded that the ground on which Pompeii stands has not been materially changed in level since an early date. But this does not prevent the adoption of the current belief that the whole shore-line has been repelled from the low Pompeiian cliff: and this repulsion is hardly to be explained

[g] Principles of Geology, bk. ii. chap. xi. vol. ii. p. 100, 5th edit.

by volcanic accumulations falling on the shallow sea-bed, without change of level. All round the Bay of Naples, proofs more or less suggestive of partial elevation of the shore present themselves to observation and interpretation.

Finally, it became a fashionable watering-place, the home of wealth and dissipation, with a handsome forum and a noble amphitheatre. Columella notices it favourably:—

> 'Quæ dulcis Pompeia palus vicina salinis
> Herculeis [b].'

The earliest portions of the stone walls of Pompeii have the character of solidity and simplicity which belongs to their remote construction; the stones are laid without mortar in parallel, or almost parallel, courses, but they are not squared at the ends, and the joints are not vertical, as in all the later styles of Greece and Etruria. Nor is it the earliest style of wall, built of unhewn polygonal stones, usually called Cyclopæan, and exemplified in Mycenæ, for that was not bedded at all, but it may be regarded as of the intermediate age to which some walls yet visible at Cumæ belong—let us call it Pelasgian.

The peculiarities of the Cyclopæan, Pelasgian, and several later styles, are in a great degree dependent on the nature and ordinary divisions of the rocks of the district. Mr. Pentland has made the suggestive remark that the polygonal style, in its perfection, occurs only in limestone districts, and his observations apply as well

[b] Lib. xv. 135.

to the old Apennine cities as to Greece and other countries which he has explored [i]. In the Campanian plain, granular tufa, easily wrought, calcareous travertine of firmer consistency, hard lava of ancient date, and bricks of good quality were at the disposal of the builders.

Diagram I. STREET IN POMPEII, shewing the polygonal pavement and the stepping-stones.

All were employed: lava, travertine, and tufa, without mortar, in the walls; hard lava in the street pavement; bricks in later constructions, with marbles, statues, stucco, and wall-painting.

[i] Rude polygonal walls are formed in some tracts of granite and syenite, as at Mount Sorrel, of blocks of all sizes and magnitudes, with or without mortar. These walls are of various dates, none very ancient.

Of all that meets the eye in the interior of Pompeii nothing appears so old in style as the pavement, which, except by occasional mendings, may be readily believed to have been laid by Pelasgian hands at the building of the city. This polygonal pavement—its hard solid blocks worn by the traffic of a thousand years before the beginning of our era, specially planned for the passage of the bigæ, between raised footways with convenient stepping-stones—excites, and deserves to excite, more wonder than all the bright columns, and baths, and fountains, and grottoes, and flesh-coloured frescoes, of this gay and luxurious city.

Of other sights, few interested us more than the dwelling of the careful artisan, whose oven is like our own, but whose mill for corn-grinding is that of the Hebrew and Oriental, if not of all early nations; the hand-mill of Scripture, the quern of our own country.

Among other points of wall structure, useful to be considered by British archæologists, is the character of the stone-work called 'opus reticulatum,' which appears in so many of the Roman walls of all ages and uses. The small squared stones, squared at least in front, placed diagonally in the building, give a somewhat picturesque surface, probably worth the attention of our 'revivalists:' and occasionally the curious fact appears of the superior durability of Roman or Cumæan mortar to the Campanian stone: for this is often eaten away by time, while the mortar is prominent like the cell-walls of the honeycomb. In this 'opus reticulatum' we may see the origin of herring-bone Saxon work, the

difference being due to the laminar stone employed by the later masons.

Another thing of interest in these old walls is the structure of the bonding courses, which are usually

Diagram II. INTERIOR OF BAKER'S HOUSE IN POMPEII, with the hand-mill and oven. The house-pavement is polygonal, as is that of the street with its curb-stone border.

employed to 'tie together' and strengthen the brick-work. In England the Roman camp walls at York and Silchester may be cited for examples of this important feature, the York bond being made of broad bricks (twenty inches square) laid in several courses among squared small stone, the Silchester work being made of broad stones laid among flint-work; the flints in one case and the stone in the other being set and 'run together' by a liquid mortar. Very much broader

bricks than any seen in England are found in Roman and earlier than Roman buildings in Etruria and Campania. They are laid in horizontal courses for the same bonding purposes in Pompeii and at Cumæ, especially in the magnificent arch over the road to the latter city. We might with advantage employ such a method in our day, especially as the economy and comfort of good dry brick buildings become better appreciated among us.

Pompeii was overwhelmed with dry ashes; in fact light-coloured pumiceous lapilli. Some of the stones were found by Hamilton to weigh eight pounds. He supposes only one continuous ashy shower—or at least the shower of one eruption, that of A.D. 79. The stones were found to be of less and less magnitude as the observer passed toward Castellammare, where none could be found equal to one ounce in weight.

Sir C. Lyell gives the following section of the materials which fell on Pompeii, and lay in thin horizontal strata near the amphitheatre (A.D. 1828):—

	ft.	in.
1. Black sparkling sand, from the eruption of 1822, containing minute regularly formed crystals of augite and tourmaline [k], from 2 to 3 in.	0	2½
2. Vegetable mould	3	0
3. Brown incoherent tuff, full of pisolitic globules in layers, from ½ in. to 3 in. in thickness ..	1	6
4. Small scoriæ and white lapilli	0	3
5. Brown earthy tuff, with numerous pisolitic globules	0	9
6. Brown earthy tuff with lapilli divided into layers	4	0
7. Layers of whitish lapilli	0	1
8. Grey solid tuff	0	3
9. Pumice and white lapilli	0	3
	10	4

[k] Not usually mentioned among Vesuvian minerals.

Near the north-western gate of Pompeii may be seen part of the old ground on which and against which some of the houses were built. Lapilli—whitish pumice—about two feet thick, may be seen covering several parallel layers of pale brown tuff, with bands of 'mesolites,' (as the guides called the soft pisolitic globules,) and layers of ashes and fragments, in all about five feet. In another place, similar layers, and above them irregular cellular masses of leucitic scoriæ, and leucitic lava—looking like the top or 'colmo' of a 'corrente.' The crystals of leucite are very numerous, and may be gathered in dozens. There is no doubt about the fact that Pompeii was built on a mass of volcanic aggregates derived from Somma, among whose products leucite is frequent. Professor Forbes assures us that 'even below the buildings of Pompeii vegetable mould is found, and no less than three successive strata of black lava containing leucite, which carry us back to the most remote antiquity[1].'

If Pompeii was destroyed by one eruption, Herculaneum, nearer to the focus of mischief, was injured by several assaults, and buried under a deeper load of ruins.

This city is more frequently named in Roman story than its neighbour Pompeii, to which it may perhaps have borne the same relation that an old county and seaport town bears to a modern watering-place. For it was a sea-port; or rather Retina was its port, succeeded by Resina. Its traditions go back to the

[1] Physical Notices of the Bay of Naples, Brewster's Edinburgh Journal, 10, p. 129.

heroic age, and centre in Hercules. The name tells us so much—the spelling being, in Cicero and Pliny, Herculanium; in Livy and Seneca, Herculaneum; in Strabo, Ἡράκλειον. Ovid calls it Urbs Herculea; and we have already seen the reference to it in Martial. A claim is however set up for Phœnicia, and Her-Koli, 'burning mountain,' is submitted for approval. Strabo describes it as terminating by a projection into the sea, and ventilated by the south-west wind [Africus], so as to be remarkably healthy.

On this devoted place, ashy showers and mud eruptions have been poured several times since it was known to the classical authors who have mentioned it. Sir W. Hamilton says,—'The matter which covers the ancient town of Herculaneum is not the produce of one eruption only; for there are evident marks that the matter of six eruptions has taken its course over that which lies immediately above the town, and was the cause of its destruction. These strata are either of lava or burnt matter, with veins of good soil between them [m]. The stratum of erupted matter that immediately covers the town, and with which the theatre and most of the houses were filled, is not of that foul vitrified matter called lava, but of a sort of soft stone, composed of pumice, ashes, and burnt matter. It is exactly of the same nature with what is called here the Naples stone: the Italians distinguish it by the name of *tufa*, and it is in general use for

[m] In these layers of soil, Lippi states that he collected a considerable number of land-shells.

building. Its colour is usually that of our freestone, but sometimes tinged with grey, green, and yellow; and the pumice stones with which it ever abounds are sometimes large and sometimes small: it varies likewise in its degree of solidity.'

He goes on to say, that after comparing this tufa with the dry pozzolana, and the substance of the new mountain near Pozzuoli, he is convinced that the first matter that issued from Vesuvius and covered Herculaneum was in a state of liquid mud. A circumstance which he regards as strongly favouring his opinion, was, that he saw the head of an antique statue dug out of this matter within the theatre of Herculaneum, 'the impression of its face remaining to this day in the tufa, and might serve as a mould for a cast in plaster of Paris, being as perfect as any mould I ever saw [n].'

The deposits which cover Herculaneum were found by Hamilton to be never less than seventy, but in some parts one hundred and twelve feet below the surface of the earth. Lyell, quoting De la Torre, informs us that there is in one part of this superposed mass a bed of true siliceous lava; and as no such current is believed to have flowed from Vesuvius till near one thousand years after the destruction of Herculaneum, 'we must conclude,' Sir C. Lyell thinks, 'that a large part of the covering of Herculaneum was long subsequent to the first inhumation of the place.' The lava current was probably that of A.D. 1631. There is no clear record of the previous eruptions, but all records are full of lacunæ,

[n] Letter v.

and the early history of Vesuvius must be held to be broken by many.

In consequence probably of the accumulations over Herculaneum being largely composed of volcanic mud —whether thrown out of the crater, as Hamilton thought, or gathered by the rains which often accompany eruptions—the state of preservation of some objects, especially papyri, is more favourable at this place than at Pompeii.

Though but a small part of Herculaneum is yet explored, a difficult task to execute under the streets of a busy living town,—'inter vivos mortua quærentes'—the number of bronze statues and valuable sculptures found is considerable, and it is likely that further discoveries of high value to literature and art may reward the researches of regenerated Italy.

CHAPTER III.

VESUVIUS IN ERUPTION TO A.D. 1800.

'Vesuvius contains inexhaustible fountains of fire.'
DION CASSIUS.

THOUGH we may admit with Sir W. Hamilton that several eruptions of Vesuvius had spread clouds of ashes and discharged rivers of mud over Herculaneum between A.D. 79 and A.D. 1036, when lava is believed to have issued from the crater, certainly the great convulsion in the reign of Titus continued for a long time to be in memory as the one great effort of the volcano. Dion Cassius, writing in the early part of the third century, strongly expresses this feeling, as we have seen in the previous chapter. With Galen he records one eruption in the reign of Severus, A.D. 203. In his sixty-sixth Book he says, under the date A.U.C. 832,—

'About this time happened in Campania some fearful and wonderful events. In autumn arose a mighty conflagration. The mountain Vesuvius (Βεσβίον), situate near the sea and the city of Naples, possesses inexhaustible fountains of fire; and formerly it was all of equal height, and the fire arose from the centre. For

B. C. [illegible]

Newbald & Stead, Lith. York.

A.D. 79.

only the middle is burning, but the outer part has been wholly free from fire to this day. On this account, while these parts are always unburnt, and the middle parts consumed and turned to ashes, the surrounding crests preserve their ancient height, but the burning parts wasted by time, sink down and form a cavity, so that the whole mountain (to compare small things with great) resembles an amphitheatre [κυνηγετικῷ τινι θεάτρῳ]. And the summits [ἄκρα] are clothed with trees and vines, but the interior circle is abandoned to fire, and throws up smoke by day and flame by night, as if many and various kinds of incense were rising. And it always is so, with more or less intensity, and often ashes are projected and fall in great quantity, and stones thrown up, under the influence of the wind [ὅταν ὑπὸ πνεύματος ἐκβιασθῇ]. And the mountain echoes and bellows, because it has not wide but narrow and secret air-passages [ἀναπνοάς] [a].'

From this account one may probably conclude that nothing like the modern cone of Vesuvius was known; but that some idea was preserved of a mountain-top, more elevated and more contracted, than that left after the eruption of A.D. 79. Also it seems a fair inference that many eruptions before his day, and during his own experience, passed without special record by Dion.

Galen is usually quoted for an account of this eruption. What I find on the subject is in his fifth book, where,

[a] This translation is made from the text of Reimarus, fol. 1750, lib. lxvi. tit. xi. cap. 21. Another translation is given in Pompeii, vol. i.

speaking of the quality of the air and agreeable conditions of life at Tabiæ [Stabiæ], he mentions Vesuvius :—

'In the depth of the bay is another mountain, and not an inconsiderable one, which both the older Roman historians and the more diligent moderns name Vesuvius —a celebrated and well-known name, on account of the fire which is thrown up from the mountain. Which thing seems to me to conduce not a little to the dryness of the air; moreover, there is no stagnant water, nor any marsh, nor any considerable river in the bay. [Before A.D. 79 the Sarno was navigable.] Vesuvius is exposed to all the winds from the north and north-west, and abundance of ashes is driven from it to the sea—the products of the combustion within.'

In A.D. 472 an eruption is reported to have occurred which covered all Europe with fine ashes, and spread alarm even at Constantinople, where it was commemorated annually on the eighth of the Ides of November. The Emperor Leo retired from the capital on this occasion [b].

A.D. 512. Marcus Aurelius Cassiodorus, Consul at Rome under Theodoric, in the fiftieth letter of his fourth Book describes the injuries caused by this eruption in Campania. The following account refers to this eruption, and perhaps to the previous one :—

'Procopius in Campania got together 500 souldiers, and ships freighted with corn, and when Antonina came, she took care with him to set out the fleet.

[b] Sigonius, Hist. of the Western Empire, Bk. xiv.

Vesuvius then bellowed, but did not cast up, which was expected: and the inhabitants were terribly frighted. This mountain stands eight miles three-quarters from Naples northward, steep, and thick with wood below, and above craggy and very wild. At the top is a deep cave, seeming to reach to the bottom of the mountaine, and if you peep in, you may see fire, which ordinarily keeps in, not troubling the people. But when the mountain bellowes like an Oxe, soon after it casts out far away a huge quantity of cynders, which catching a man upon the way, he hath no means to save his life: if it falls upon houses, they fall with the weight: if the wind blow stiff, it rises past ones sight, and is carryed by the wind to very farr countryes. They say it fell once in Constantinople, which so frightened the citizens, that to this day they have yearly publick supplications to appease God: and that another time it fell in Tripolis. Formerly this bellowing came every 100 yeares or more, but since oftner. When the Vesuvius casts out cynders, they are confident of a plentifull year: the aire about it is pure, and none more healthy: that the Physitians send thither men far gone in consumptions [c].'

A.D. 685. Sabellius, Sigonius, and Paulus Diaconus are quoted as authorities.

A.D. 993. On the authority of Glabrus Rudolphus, a monk of Cluny.

[c] Procopius' History of the Gothic Warrs, Englished by Henry Holcroft, Knight. London: Printed for Humphrey Moseley, and are to be sold at his shop at the Princes Armes in St. Paul's Churchyard. 1653. Book ii. chap. iv.

We now enter upon a series of eruptions with useful general guides, D. Ignazio Sorrentino, Sacerdote Secolare della Torre del Greco, whose work, entitled Istoria del Monte Vesuvio, appeared in A.D. 1734; and Padre Della Torre, whose volumes, entitled Storia e Fenomini del Vesuvio, A.D. 1758, and Incendio del Vesuvio, A.D. 1767, were printed at Naples in the years named.

A.D. 1036. Francis Scot, in his Itinerary of Italy, relates, concerning this eruption, that it happened not only from the top but from the sides, and that its burning products ran to the sea.

A.D. 1049. Leo Marsicanus, a monk of Monte Cassino, reports the lava-currents as running to the sea.

A.D. 1138. Mentioned in the Chronicle of Monte Cassino.

A.D. 1139. Sorrentino reports, on the authority of Falcone Beneventano, Secretary to Pope Innocent II, that Vesuvius erupted with a great conflagration for eight days (ignem validum et flammas projecit), and threw up so much dust and stones for thirty days, that the whole interior was consumed. The crater, he says, remained empty from this time to A.D. 1631. From A.D. 1139 to A.D. 1631 no important eruption is admitted by Sorrentino; and Sir W. Hamilton says, 'There was no eruption from the great crater of Vesuvius from the year 1139 to the great eruption of 1631, and the top of the mountain began to lose all signs of fire.' The following are, however, mentioned.

A.D. 1306. On the authority of Leandro Alberti in his Description of Italy.

A.D. 1500. On the report of Dr. Ambrogio Leone da Nola, who speaks of an eruption of ashes.

According to Sir W. Hamilton, the lists of eruptions of Ætna and Vesuvius which he gives could not have been compiled but for the curious fact that sacred images and vestments were employed to stop the fury of the fires—the veil of St. Agatha in Sicily, and the relics of St. Januarius at Naples; the record of the triumphant interference of the saints being carefully preserved by the priests. The inhabitants of Naples, he remarks, in a letter to Sir Joseph Banks, Oct. 1, A.D. 1779, give so little attention to Mount Vesuvius, though in full view of the greatest part of it, that he is convinced many of its eruptions pass quite unnoticed by at least two-thirds of them.

In December, A.D. 1631, occurred the great convulsion, whose memorials are written widely on the western face of Vesuvius in ruined villages, and left in layers of ashes over hundreds of miles of country, or in heaps of mud swept down by hot-water floods from the crater. The crater itself was dissipated in the convulsion. The Abate Giulio Cesare Braccini, who examined the mountain not long before the eruption of A.D. 1631, found apparently no cone or mount like the modern Vesuvius. 'The crater was five miles in circumference, and about a thousand paces deep[d]; its sides were covered with forest-trees and brushwood, and at

[d] The meaning may perhaps be so many paces of sloping descent. One thousand paces make a geographical mile: each pace equals 6·113 English feet: a palm is $10\frac{4}{10}$ inches.

the bottom there was a plain on which cattle grazed. In the woody parts wild boars frequently harboured. In the midst of the plain, within the crater, was a narrow passage, through which, by a winding path, you could descend about a mile amongst rocks and stones till you came to another more spacious plain, covered with ashes; in this plain were three little pools placed in the triangular form, one towards the east, of hot water, corrosive and bitter beyond measure; another towards the west, of water salter than that of the sea; the third of hot water that had no particular taste.'

In this account, extracted by Sir W. Hamilton from Sorrentino, the whole is rather confused. Still we perceive that the mountain had, after long rest, assumed much of the aspect which it wore at the first opening of its history in the days of Spartacus. A crater five miles in circumference would correspond pretty nearly with that which served the gladiators for a camp. The repose of centuries was broken by a convulsion as terrible as any on record.

Six months of continued earthquakes, which grew more violent toward the end of A.D. 1631, heralded the eruption, which, as usual, began by terrific noises in the interior of the mountain, like a tempestuous sea; as if a body of water, like that of the river Dragone (a branch of the Sarno), had been swallowed up. Some of the neighbouring people ascended the mountain, and found the vast crater full, and beginning to smoke from some liquid parts. The inhabitants of the coast were thus warned, and had several days to arrange for

their safety, but in the end a great part of Torre del Greco was destroyed, and a like fate overtook Resina and Granatello, with a great loss of life, reported at 18,000 persons.

It was in the morning of Wednesday, December 16th, A.D. 1631, that the eruption began, with uncommon force, from a point on the depressed broad cone of that day, which in no degree represented the Vesuvius of our time, exactly west of the axis of fire. This is according to the map of M. Le Hon, and is probably correct. It is a quarter from which many eruptions have happened. The lava, whether it came from the edge or flank of the broad open crater of Braccini, may be supposed to have started at about 3,000 feet above the sea level, and to have gathered in the Piano della Ginestra and flowed round to the Pedimentina, threatening at once Resina, Torre del Greco, and Torre dell' Annunziata. Nor were its warnings vain. Right downward in several streams over the steep circular edge of the ancient crater of Somma, for a large part of its western outline, a quadrant of the circumference, the lava rushed forward and reached the sea-coast at twelve or thirteen points, often in broad masses which still cap the cliffs of looser materials. The length of some of the streams of lava was five miles; the interval between their extremities, seven and a-half.

Still more astonishing were the vast columns of dust and vapour, which rose above the mountain in the traditional form of the pine-tree, and then, transported by the winds, passed over a hundred miles of country,

and even reached the Adriatic and Constantinople. The moving clouds were highly charged with electricity, and darted ferilli on all sides to the destruction of men and animals. Clouds condensed into tempests of rain, and hot water from the mountain, mixed with volcanic mud, deluged the neighbourhood, and even reached Nola and the Apennines. In this violent paroxysm the whole top of the mountain is believed to have been swept away, and the edge of the great crateral hollow which took its place greatly lowered. Nor was the sea unmoved. It retired during the violent earthquakes, and then returned full thirty paces beyond its former limit.

'Braccini, in his account of the eruption of A.D. 1631, says that he found many sorts of sea-shells on Vesuvius after that eruption; and P. Ignatio, in his account of the same eruption, says that he and his companion picked up many shells at that time upon the mountain. This circumstance would induce one to believe that the water thrown out of Vesuvius during that formidable eruption came from the sea [e].'

After this terrific disturbance, itself sixteen centuries removed from the ever-memorable Plinian catastrophe, Vesuvius has never been really at rest; but no following eruption for more than a century appears to have come up to the popular idea of a grand convulsion. It would seem that after the extraordinary evacuation of the large crateral space in A.D. 1631, the usual process was resumed, by which it was partly refilled and the funnel choked.

[e] Hamilton, Letter v.

In July, 1660, a considerable ejection of ashes occurred, which cleared out the crater, changing its aspect, and left an abyss in the interior, with an estimated depth of 2,000 paces, inaccessible through the steepness of the walls[f]. The circuit is stated at five miles.

After A.D. 1660 Vesuvius was in frequent but not strong eruption. According to Sorrentino, once a year, every two, or at most every three years, it erupted, and then ceased for six years. During much of this period three mouths were in feeble eruption, raising the level of the interior; three eruptive mouths were noticed by Sorrentino in A.D. 1670, perhaps corresponding with the three pools mentioned by Braccini before the eruption of A.D. 1631.

In A.D. 1682, earthquakes, happening in August, alarmed the inhabitants of Torre, who according to their custom ascended Vesuvius to observe its condition. On the 12th the three mouths became active; the great 'pine-tree' of clouds, flame, cinders, and stones arose, producing great terror, and much religious exercise, which Sorrentino describes in a lively manner. One of the explosions shook a chandelier from the altar in the church of Santa Croce. Some of the Torresians expecting a return of the disasters of A.D. 1631, and that the sea would flow into Vesuvius, watchmen were stationed on the mountain, and by the sea-side, to give notice of the danger. Falling without rain, the dry

[f] Sorrentino, Bk. ii. cap. i. p. 111: 'Da niun lato si potera discendere.'

ashes did no great harm, about Torre del Greco, to grapes and other fruit.

By the changes effected on this occasion and in following years, the crater was again partly filled, and ashes accumulated in its centre, but no discharge happened from the summit till A.D. 1694.

A.D. 1685. For three years the often troubled and altered crater was at rest: peasants and citizens looked over the edge into a cavernous and broken surface, to the depths of which they could not penetrate. In October, 1685, Sorrentino ascended the mountain with some clerical companions at night, to watch the phænomena; and found stones falling beyond the crater, on the slope of the mountain. Alarmed in time, they hurried to the hermitage of San Salvatore, and saw, on looking back, the spot where they had stationed themselves covered with great stones which had been thrown out. A considerable eruption followed, which left a 'new mountain' within, and higher than the old one, and visible from Naples. Sorrentino remembered no further eruption till A.D. 1689; at least none worthy of record; 'small eruptions there may have been, however, for such have hardly ever been counted or kept in memory.'

A.D. 1689. A considerable eruption. The large crater was nearly filled by successive ejections, which had so increased the small cone in it, as to give the appearance of a single cone 300 palms higher than before. This, as to place, was where Vesuvius now stands, but as to height, was very much inferior.

A.D. 1694. April 13, a stream of lava ran from the

little cone just described, into the deep Fosso dei Corvi, near the Salvatore, like black pitch. Here it divided into two branches, one of which appeared fifteen palms wide and eight deep. The eruption lasted altogether fifteen days, and in the course of it threatened Giorgio a Cremano, Resina, and Torre del Greco.

A.D. 1696. No sign of further disturbance till July of this year, when the summit of the small discharging cone was found to be covered with sulphur, a sign of approaching eruption, which did in fact occur from the 31st of July to the 10th of August, or some days later.

A.D. 1697. On the fifteenth of September, the cone on the mountain burst, and through three apertures an immense current flowed, and the volcano continued to manifest activity till November.

The mountain continued to smoke continually from the latter part of A.D. 1697; and in the beginning of May, 1698, the fumes changed colour, earthquakes occurred, and quickly were seen flames over the furnace mouths of the volcano. On the 19th, the fire gathered strength, with tremendous crashes, and earth-shakings, and increased day by day, till on the 25th, a torrent rushed down towards Resina, spread on the Plain, and dividing into two streams, one running toward the Salvatore, the other towards the Fosso dei Corvi. These currents ceased on the 28th, and then an overflow came from the summit, running toward Torre del Greco, till the 2nd of June. After the currents had expended themselves, great explosions of ashes occurred, and heavy rains, which did far greater mischief to vines and growing

plants than dry ashes usually do. The dust-showers reached Capri, Sorrento, Castellammare, Gragnano, and Lettera, and everywhere proved very hurtful, through the 'pestiferous water' which accompanied them. On the 14th of May, at 10 o'clock, before the eruption began, the water shallowed five successive times in the Bay of Naples [g]. In one part of this eruption the ejected matters are said to have been raised many miles (molte miglia) in the air—with terrible thunder and lightning. This very considerable eruption lasted till the middle of July, and at the close the crater was full of lava and stony masses,—one fierce explosion at the end.

About the commencement of the eighteenth century original sources of information begin to be accessible to the English reader, and English writers of credit become authorities of value. Sorrentino and Della Torre are still our trusty guides.

In A.D. 1701, Vesuvius resumed activity. On the 1st of July occurred a terrible shock, with a globe of dust and stones; immediately afterwards a fissure opened at the foot of the mountain on the eastern side, whence came the roar and flame of the volcano, and a 'pine-tree' of great height containing ashes and stones.

On the 2nd of July, a torrent of fire swept over the edge of the old mountain; then it divided into two streams, one, the larger, running by the Cognolo

[g] Sorrentino, Bk. ii. cap. vii.

d' Ottajano to the east, another, smaller, at first towards Viulo westward, but then it was deflected eastward. This small current was fifty paces broad and fifteen palms in depth, the other much larger. The eruption lasted, with fits and starts, to the middle of the month.

A.D. 1704. From small mouths, which remained of the last eruption, smoke and flame issued on the 19th of March, and on the 20th a column of liquid fire shot up more than two miles in the air, with fearful crashes when the rising and falling materials met in their courses.

A.D. 1705. Jan. 19th is marked as a day of disturbance, among others of lesser note.

A.D. 1706. From the date last named to the middle of June in this year, other disturbances, the whole ceasing on the 23rd of June.

A.D. 1707. After a period of partial tranquillity, the mountain became agitated late in July, and threw up the usual pine-column, and cinders a mile in air, with fearful noises; a stream of lava flowed to the Salvatore; and heavy showers of stones fell about Bosco and Viulo. In the course of the eruption, the thunder of Vesuvius was heard at enormous distances, and volcanic lightning shot over Naples to Pausilippo, from dusty clouds of preternatural darkness. Lava flowed almost to the sea, and heavy rains following did unusual damage to the vineyards.

A.D. 1708. On the 14th of August, a moderate explosion, with a burst of a sphere of ashes, which lasted a quarter of an hour, and then ceased.

A.D. 1712. This whole year was troubled by eruptions, of the usual character, with varying force, from February to November. In April the crater was full to overflowing, and lava ran down to the Piano, and toward the Fosso Bianco, the currents moving for eight days. Through May and June, and even to October and November, some eruption phænomena were continued.

A.D. 1713[h]. Sorrentino states that the crater was emptied by the eruption of A.D. 1712; but on the 12th of April, 1713, appeared the usual signs above the volcano, and on the 24th a feeble eruption occurred, and in May, a current ran toward the Fosso dei Corvi, paused, and was refreshed by new streams, which took their course toward Ottajano. Later in the month other currents ran toward Torre and Resina, nor did the eruption, rising and falling in energy, cease till the 25th of May.

A.D. 1714. On the 6th of January Vesuvius hung out the usual signals; flames and explosions followed, and lava and red-hot stones were so abundant that both the old and new mountain seemed lost in fire. After one hour's duration the excitement was abated, but from time to time explosions, and one very violent shock, occurred.

Again, on the 15th of June, the fever returned; on the 21st it became violent, and 'all the three mouths' tossed up liquid columns, stones, and the 'pine-tree' of

[h] Misprinted 1717 in Sorrentino's book, p. 167.

ashes, more than a mile, with tremendous uproar. The lava ran in considerable quantity southward toward Bosco Tre Case, which it reached, ending about a mile from the sea.

Fresh streams on the 22nd, toward both the east and the south; a fresh outburst on the 23rd; more ashy eruptions from the summit on the 24th; rain and a pause; a religious procession on the 26th; renewed disturbances to the 30th.

Toward the end of this eruption, the sea retired seven paces, leaving dry, fishes and a boat, for a quarter of an hour; sucked in, it was supposed, to the 'viscera' of Vesuvius.

A.D. 1716. To the sea water admitted, according to the supposition, to the interior of Vesuvius on the 30th of June, 1714, is attributed great mischief. For this being evaporated, and charged with hurtful qualities, destroyed or injured the vines and the produce of the vineyards, much more than the fall of stones and ashes.

Earthquakes happened in A.D. 1716, which seem to have been severe, in the personal experience of Sorrentino, and in April a small explosion happened.

A.D. 1717. No further disturbance of importance till in January, 1717, symptoms of returning activity appeared, which in June were realized. On the 6th a large fissure opened on the south side, and gave passage to a lava as broad as the Tiber at Rome. This divided itself on the 'Plain of the old mountain' into two streams. One ran eastward over the solidified

current of A.D. 1714, the other toward the Fosso Bianco, into which deep cavity it continually flowed. Again the abundant liquid fire divided itself, some running toward Bosco, the greater part toward Torre del Greco. Great injury was done to the vineyards, and had it continued to flow a few hours more, they must have been destroyed; from which, Sorrentino observes, it may be believed that God arrested it, on the supplication of his beloved San Gennaro, who was specially entreated by the terrified people of Tre Case in the face of the 'horrible mountain.'

On the 9th, more and stronger streams of lava—more terror and supplication. On the 10th, not rivers, but mountains of melted rock, passed over the ruined vineyards of Langella, Aurilia, and Leone, filling a valley in the territory of Grazini, and continuing its fatal course beyond.

On the 13th, rising in all its might, the lava overfilled the great fissure, topped in four overflowing streams the edge of the crater, and collected there into a mass a mile broad, from which it threatened all the slope.

On the 18th of the month the eruption of lava ended, but smoke and traces of fire were seen for some time after, indeed they hardly ceased before a new eruption began.

In April of this year the celebrated Bishop Berkeley ascended the mountain, and found, in the midst of noise and smoke, the means of examining the summit, which then had a flat interior, with two 'furnaces' near together, which glowed with red fire, and ejected red-

hot stones. One of these 'furnaces' was estimated to be three yards in diameter. On the 8th of May, the crater, throwing its smoke upward, and stones from 300 to 1,000 feet above the edge, was estimated to be one mile in circumference, and 100 yards in depth. A small cone was formed in the middle, which retained the two holes or furnaces mentioned. One was in the vertex of the little cone, the other was lower in the side, like the opening in a glass-house chimney, in which might be seen the undulating fiery lava. 'All the volleys of smoke, flame, and burning stones came out of the summit, while the liquid rock wrought and overflowed in the other.' Berkeley describes the volcanic groaning and bellowing as like a mixture of tempest rage, sea murmur, and the roar of thunder and artillery, all confused together. He made a visit to the eruption by night in a boat from Naples—a Plinian visit. On the 15th walls and courts were covered with ashes in Naples [i]. It is remarked that the lava could well be seen in the Fosso Bianco, above Torre del Greco, and on the east side of the Camaldoli. M. le Hon represents this current between the Camaldoli and Viulo.

A.D. 1718. On the 3rd of September, the disquietude of Vesuvius returned; on the 16th came an outburst, the crater overflowed, and lava menaced both Resina on the west, and Bosco on the south. On the 17th other currents flowed towards Ottajano and Viulo. These phænomena ceased, and Vesuvius remained com-

[i] Phil. Trans. 1717, p. 708.

paratively tranquil, except that a new top was added to the cone, till the next year.

A.D. 1719. In July, explosions began on the 7th, and lava flowed on the 8th and 9th, above Resina toward the Salvatore, so that from the 3rd of September, 1718, to the 9th of July, the eleven months of disquiet may be regarded as one almost continual eruption.

Vesuvius continued to make feeble displays of smoke, increased with rain and strong winds, decreased with serene weather, till on the 7th of May, 1720, it began to thunder, and belch flame and throw up stones. Rain and wind concurring, the ashes were injurious at Ottajano. A great eruption was expected at Pentecost, 19th of May, the more so as the small cone at the top of the mountain was brimful, with its two mouths, one east and one south, the third to the north being a rough hollow, filled from the other. Flames and smoke rose high, but there was no great eruption: the slight indications of interior disturbance were observed by Sorrentino on this and other occasions to vary with the wind, tendency to rain, and changes of the moon, as well as the movement of the sea.

So things remained till May 1, 1721, when the summit of the crater gave forth a current, and till the 6th of June, the phænomena of eruption continued with varying energy, and then the mountain remained smoking.

A.D. 1723. Vesuvius never ceased from time to time to smoke, and show fire and eruption, with earthquake, since June 15, 1714. On March 28, 1723, Sor-

rentino found his well almost empty, and the same was observed throughout the town (Torre del Greco). The sea was observed to be lowered, windows were shaken, and by those signs an early eruption was predicted. On the 20th of April rain came with the Sirocco, and the mountain, as usual, fired up. Two mouths opened, one, toward the Apennine, gave black smoke, the other, toward the south, white vapours, with occasional explosions. Thus it continued to the 25th of June. When the Sirocco was blowing, the fire increased. On the 26th, the northern mouth kindled, and lava flowed from that side. On the 27th, a current flowed from the old mountain, toward the south, expanding to fill the great hollow under the hill of Ottajano. Then the two other mouths came into strong action, and afterwards all together. Gradually the eruptions became intermittent every quarter of an hour, then every hour, and on the 8th of July quiet was restored.

A.D. 1724. September 4, at the fifteenth hour, an eruption in the pine form. Again, at the nineteenth hour, and at the twenty-second. After many smaller efforts, a current was observed proceeding from the opening of A.D. 1717, of considerable breadth; a large portion running to the Fosso Bianco, above Torre del Greco. Among other remarkable accidents of this eruption, it is mentioned that many fragments like straw, hay, or small needle-shaped leaves or prickles, were collected [k]. At one time six streams of fire were

[k] These were conjectured by Hamilton to be analogous to the glassy fibres which were observed in the eruption of A.D. 1779.

seen from Torre, and a new vent was formed below the lip of the old mountain, at the foot of the new mountain (now one continuous cone); at another the lava spread from the Fosso under the Crocella toward Monte St. Angelo. Seen at a distance of two miles it was a vast and horrible spectacle. Thick clouds covered Vesuvius, and with a fearful noise the three mouths threw up to the sky volleys of stones, more than two miles high, 'which occupied in falling the time of five Paternosters.' No sleep that night for Torre del Greco (September 17). On the 18th the eruption continued, but less violently, and after the 19th, the festivity of San Gennaro, the mountain was no longer dangerous, though it was not quieted till the end of the month.

A.D. 1725. There still remained white vapours rising, and a considerable deposit of sal ammoniac. On the 10th of January a fresh eruption began, and on the 16th, on the side facing Somma, lava was running in the valley toward the Salvatore; on the 20th the explosions and noises increased till the 24th, when they ceased, but the lava current continued, augmenting with the strong winds, but diminishing in calm weather, till the 20th of May. Then a fresh current broke out on the west under the edge of the new crater. A succession of similar phænomena continued.

A.D. 1726. April 10, signs of a new outbreak: on the 17th a current running toward the Salvatore and the Fosso Bianco: heavy eruptions 'many miles' high. May 26, a tremendous explosion; and so on through

the year at intervals to the end, some of the eruptions being of reddened ashes.

A.D. 1727. This year opened in the same manner, or rather the eruption fever continued through January, March, April, and June, lava flowing a great part of the time, and earthquakes felt. Disturbed again in July, the mountain continued in action, making a large cone, and yielding much lava, from the 29th of that month to the 29th of the same month in A.D. 1728.

A.D. 1728. The volcano was in action till the end of July. It started again into life in the month of September, and then subsided into a smoking condition.

A.D. 1729. From this state of feebleness it was disturbed in September, but soon relapsed; exhalations, however, hardly ever ceasing.

A.D. 1730. In February, signs of revived energy; in March feeble currents of lava for two days ran towards Ottajano, and damaged the lands of the Prince. During this eruption the sea retired at Torre dell' Annunziata. In April the mountain resumed its usual aspect.

A.D. 1732. On the 29th of November, Sorrentino was rudely awakened in his country house, near Viulo, by an earthquake, which shook the whole country. On the 25th of December, the signs of eruption appeared over the mountain.

A.D. 1733. The year began with earthquake; on the 8th of January torrents of lava issued, but did not reach the lower ground; the crater was observed to be full, nor did the currents cease to flow at intervals east-

ward toward Ottajano, and westward toward Torre, even to the end of the year, and a few days in the beginning of A.D. 1734. In the course of the observations made by Sorrentino, he noticed on the 14th of June, 1733, circles of dust, two miles high above the summit of the mountain, but one mile from it, which remained suspended for a short time, and were replaced by others—an effect of whirlwind probably.

And thus something more than a century elapsed after the great eruption of A.D. 1631, a century of frequent and occasionally violent explosions, and lava currents of varying magnitude, with earthquakes and sea-movements. The last few years were almost entirely filled with eruption phænomena, rising and falling in violence, but so continual, as to lead Sorrentino, a philosopher of easy faith, to be willing to admit the axiom of his forefathers, that after Vesuvius had burned for a hundred years, it would remain at rest for a century. He concludes his interesting and valuable work with some reflections which culminate in the hope, very piously expressed, 'Che resti questa volta il nostro monte, come il Mongibello, aperto, e continuamente bruciante.'

A.D. 1737. Dr. Serao, a physician of eminence at Naples, and Professor in the University, observed and described this eruption. On the 14th of May, Vesuvius gave the sign, by smoke and gathering fire, and on the 16th, lava flowed over the lip of the crater, and collected into a torrent, which was directed toward Bosco, while stones were ejected into the air. By the

20th, these ejections became heavy showers of ashes, burnt stones, and pumice; and then the mountain broke, on the south-western side (represented in a large drawing by Della Torre), and poured out lava, to the plain which encircled the cone, where it spread into a space 500 paces long and 300 broad. Then dividing, it ran in streams toward Resina, and Torre del Greco; and on the 21st the main stream passed by and injured the monastery of the Carmelites, and finally reached the sea and became consolidated in prismatic forms. Its course was estimated by Serao to be 28,400 palms long (about five miles), and its cubic content 319,658,161 Parisian feet. The lava is rather earthy in texture, except at the end, where it is compact and prismatized. It contains pyroxene and leucite, and in the small interstices felspar[1]. Volcanic lightning accompanied the ejections from the summit, which never ceased till July, and did enormous damage by their mere weight and abundance, especially at Ottajano.

A.D. 1751. Oct. 22, at the tenth hour, according to Padre Torre, the first signs of an eruption began, which was remarkable in several respects. Immediately before it commenced, a central cone with a crateral top existed above a terrace-like broader crater. On the 25th, the south-east side of the cone broke and gave passage to two narrow streams, which ran four miles; one of them reached the village of Bosco Reale, the other came to

[1] Breislak gives the cubic content as 10,237,096 metres, or 1,479,898 toises. The statement found in English books of 33,587,058 cubic feet is very erroneous—about a tenth of the true quantity.

an end not far from Mauro. Both were very destructive of vines and vineyards, and villas and cultivated fields. After the eruption the cone disappeared, and there remained a crater of 5,624 feet in circumference, and only 120 feet deep, full of lava, stones, and dust. This was very unequal in point of level, and had one large abyss on the side toward Ottajano, full of living fire, 1,500 feet in circuit, and 500 feet deep.

Toward the extremities of the currents near Bosco and Mauro, their velocity was measured—28 palms in a minute on a considerable slope, the current being 16 palms broad, and 10 palms in a minute where the slope was less. The greatest of these velocities is above a quarter of a mile in the hour. The currents ceased in

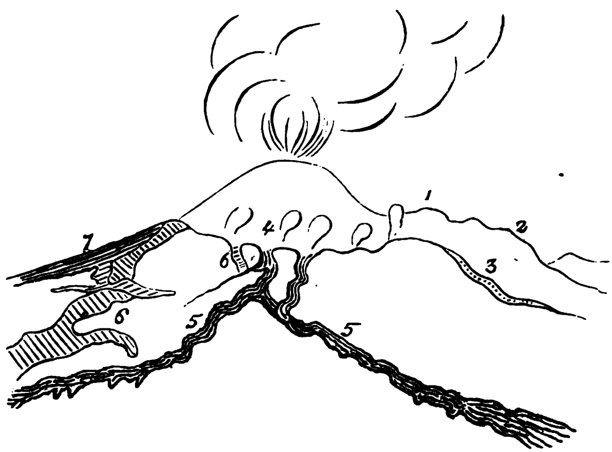


Diagram III. Vesuvius from Bosco Tre Case. (*From Della Torre.*)
1. Monte Ottajano. 2. Lava of 1723. 3. Lava of 1730. 4. Bocce of 1754 to Ottajano. 5. Lava of 1754. 6. Lava of 1751. 7. Lava of 1754 to Tre Case.

November, but heat was sensible on examination in May, 1752. In the engravings given by Della Torre, the currents of several years, beginning with A.D. 1631, and continued to A.D. 1754, are very well traced. In Diagram IV we have copied the main features.

Breislak found this lava rich in pyroxene and leucite; and while the portion which ran to Bosco was covered to a depth of two or three feet with scoriæ, that which was directed toward Mauro was quite free from such a capping, having been, no doubt, emitted in a very fluid state. It appears like some lava of later date, much contorted and implicated, with a channelled surface and stalactitical shapes. It breaks with a resinous fracture.

A.D. 1753. In May and June, the deep crater or abyss just mentioned threw up liquid and solid matter, and began to form a new monticule within.

A.D. 1754. In July, the summit of this new monticule threw up much smoke, stones, and pumice, which enlarged the mass; and on the 2nd of December, the cone broke silently, in two places, from which came two copious streams of melted rock, flowing with a velocity of 40 feet in a minute. These took the same courses as the lava of A.D. 1751, viz. one toward Bosco Reale, and the other more toward Mauro, and a third is mentioned by Le Hon, running to Tre Case. The crater from which all this mass of matter came was continually growing larger, and lava continued to flow at intervals.

A.D. 1755. The bottom of the crater was so high that the great plain in the centre of it was only 23 French feet lower than the edge, and in the centre rose

another cone 80 or 90 feet in height, having its own small crater through which its size was increased. In January, two new mouths opened, much below the summit, on the southern side of the crater, which, in April, measured 4,620 feet in circuit, instead of 1,500 feet in 1751.

Diagram IV. VIEW OF THE INTERIOR OF VESUVIUS, Feb. 23, 1755, (*from Della Torre.*) *a.* Edge of Vesuvius. *b.* Interior plain elevated 100 feet *c.* Monticule growing up.

A.D. 1757. By the continual growth of this part the whole was expanded to the diameter of the old large crater, and constituted a part of the general slope of Vesuvius—one mountain in fact—causing an elevation of 252 palms. Through the subsequent two years the accumulation of liquid matter became excessive, and an eruption followed in A.D. 1759–60.

A.D. 1759. On the 24th of November, suddenly, a violent eruption broke forth; it continued till the 4th of December to vomit forth, from five different

openings, vortices of flame with torrents of lava, which, running with impetuosity towards Torre dell' Annunziata, threatened that town and all the neighbourhood with speedy devastation [m].

A.D. 1760. On the 21st of February, and several days following, Vesuvius was overflowed by a deluge of 'burning bitumen called lava [n].'

Toward the end of the year, after a considerable interval of quiet, the mountain became fissured in a radiating direction, below the line of the Pedimentina, which represents the western crater edge of ancient Somma. On the 23rd of December this fissure, in a direction almost exactly southward, threw up two terrific black columns of smoke and ashes, which drifted to the south-east, and were widely distributed and followed by bursts of flame. The point of outburst was not more than 1,000 feet above the level of the sea. Fifteen openings appeared on the line of fissure; two of them yielded floods of lava, which united and ran in one long broad stream, 3½ miles long, and 400 feet broad, to within a quarter of a mile of the sea, about 1½ mile on the north-west side of Torre dell' Annunziata. The lava ran across the road between Torre del Greco and Torre dell' Annunziata, and stopped Sir C. Styles, who went to look at it; the mouths above raging furiously at the time, and exploding every second or two seconds like a storm of thunder. The long line of these openings (Voccole) is still traceable. The highest is represented in Diagram XXIV. Three hillocks were

[m] Annual Register, Jan. 1760. [n] Ibid. March, 1760.

thrown up on the line of the mouths, large enough to be distinguished at Naples, one of them 200 feet high.

Sir Francis Eyles Styles, Bart., then resident at Naples, communicated a description of this great eruption to the Royal Society of London. The lava is rich in crystals of pyroxene, and among the scoriæ small crystals of specular iron abound. The crater measured in this year by M. de Bottis was 5,624 French feet in circumference, and 130 feet deep.

A.D. 1761. Jan. 8th, an eruption began at night and ceased on the 9th. On the 12th, with much noise the whole crater top fell in.

July. One of the bocce, which opened in A.D. 1760, still emitted smoke and appearance of flame.

The history of Vesuvian eruptions grows exact in the interesting letters addressed to the Royal Society by Sir William Hamilton, Ambassador at the Court of Naples. These letters, of dates between June 10, 1766, and May 1, 1776, contain a series of excellent, almost daily notices of the progress of several eruptions, and reflections on the nature and causes of particular effects, which show him to have been a judicious as well as careful explorer in natural science.

Arriving in Naples in Nov. 1764, he began to observe; and during a long residence kept the mountain under thoughtful inspection; the result is an admirable history for the period of fifteen years. There were two publications separate from the Transactions of the Royal Society; one in 8vo, with a few engravings, contains seven letters, the last dated Nov. 5, 1771; the other,

a large and splendid folio, with coloured illustrations, entitled Campi Phlegræi, which, with a supplement, brings down the records to A.D. 1779.

In September, 1765, the vapours evolved from Vesuvius grew to be considerable; in October, black smoke mixed with the steam clouds; and at night red tints appeared in these smoky wreaths. In November, the mountain being covered with snow, a 'hillock of sulphur,' about six feet high, which had been recently thrown up, gave forth a light blue flame from the top. While examining it, Sir W. Hamilton heard a violent report, and saw a column of black smoke, followed by a reddish flame, shoot up from the mouth of the volcano; and presently fell a shower of stones, one of which dropped near him, and alarmed him into more cautious proceedings in subsequent journeys to Vesuvius. The eruption, of which these smoke ejections were prophetic or preparatory, began on Good Friday, the 28th of March, 1766. A few days previously, the great and fatal image of the pine-tree appeared above the crater, and at night the smoke appeared like flame. On the day named, a violent explosion and shower of red-hot cinders occurred. At seven o'clock in the evening, the lava began to boil over the mouth of the volcano, at first in one stream, and soon after dividing itself into two, it took its course toward Portici. The author left Naples, and remained all night on the mountain. The lava ran near a mile in an hour's time, when the two branches joined in a hollow on the side of the mountain, without proceeding farther. The lava

had the appearance of a river of red-hot and liquid metal, such as we see in the glass-houses, on which were large floating cinders, half lighted, and rolling one over another with great precipitation down the side of the mountain, forming a most beautiful and uncommon cascade. As the eruption proceeded, the lava which was at first pale and bright, became of a deep red. In daylight it scarcely seemed fiery, but a thick white smoke marked its course.

The eruption was suspended on the 29th, but recovered its energy on the 30th, stones being thrown to a great height every minute. On the 31st, the red translucid stones ejected were supposed to weigh a ton, and to have been thrown up 200 feet at least. A little central cone was now in process of being formed within the crater by the aggregation of the ashes and stones, and the access to the edge of the old crater was rendered safer. Three English gentlemen who had approached too near, some days before the eruption, were seriously hurt by the stones falling.

From the 31st of March to the 9th of April, these phænomena were repeated, with intermissions in the fever of the mountain, which seemed to return with violence every other night.

On the 10th of April, at night, the lava disappeared from the side of the mountain toward Naples, and broke out with more violence toward Torre dell' Annunziata. The diligent representative of English science and the English Government remained the whole day and night of the 12th of April upon the mountain, and followed the

course of the lava to its very source, which was a clear outburst from the side of the cone about half a mile from the mouth of the volcano. It flowed like a torrent, with violent explosions and earth-skakings; the heat was such as to forbid a nearer approach than 10 feet; the consistency of the lava was such that a stick made no impression, and stones thrown forcibly on the current did not sink in it. It ran with amazing velocity; 'in the first mile, with a rapidity equal to that of the river Severn at the passage near Bristol.' 'The stream at its source was about 10 feet wide, but soon extended itself, and has divided into three branches, so that three rivers of fire, communicating their heat to the cinders of former lavas, between one branch and the other, had the appearance at night of a continued sheet of fire, four miles in length, and in some parts near two in breadth [o].' After running pure for about a hundred yards, the lava began to collect cinders, stones, &c, and a scum was formed on its surface, so that the whole appearance was like that of the river Thames, after a hard frost and great fall of snow, when beginning to thaw, carrying down vast masses of snow and ice. In two places the lava disappeared in a subterranean passage, and then came out again free from the scum. The vineyards and cottages were injured or destroyed, in spite of the opposition of many images of St. Januarius, which were placed upon the cottages and vines. The lower end of the current was covered by red-hot stones,—

[o] These estimates are in excess. Hamilton had not the good maps which we now possess.

a kind of wall 10 or 12 feet high, which rolled on irregularly and slowly about 30 feet in an hour. The lava continued to flow at intervals, with ejections of ashes and stones, till the early part of June, and even till the 10th of December, 1766.

From the 10th of December to March, 1767, Vesuvius was quiet; then it began to throw up stones from time to time; in April the throws were more frequent, and at night a red glare was visible on the cloudy columns which hung over the crater. These repeated throws of cinders, ashes, and pumice-stones increased the small cone of eruption which had been left in the centre of the flat crateral space so much that its tòp became visible at a distance.

On the 7th of August there issued a small stream of lava, from a breach in the side of the small cone; the lava gradually filled the space between the cone and the crateral edge; on the 12th of September it overflowed the crater, and ran down the mountain. Stones were ejected which took ten seconds in their fall, from which it may be computed that the height which the stones reached was 1,600 feet. Padre Torre, a great observer of Vesuvius, says they went up above a thousand feet. The lava ceased on the 18th of October, but rushed out at a different place at 8 a.m. of the 19th, after volleys of stones thrown to an immense height, and the reappearance of the huge traditional pine-tree of smoke. On this occasion that vast phantom extended its menacing shadow over Capri, at a distance of 28 miles from Vesuvius. The lava at first came out of a mouth

about 100 yards below the crater, on the side toward Monte Somma. While occupied in viewing this current, the observer heard a violent noise within the mountain; saw it split at a quarter of a mile distance; and saw from the new mouth a fountain of liquid fire shoot up many feet, and then, like a torrent, roll on toward him. The earth shook; stones fell thick around him; dense clouds of ashes darkened the air; loud thunders came from the mountain top, and the party took to precipitate flight. The account is too lively and instructive to be omitted.

'I was making my observations upon the lava, which had already, from the spot where it first broke out, reached the valley, when, on a sudden, about noon, I heard a violent noise within the mountain, and at the spot C, about a quarter of a mile off the place where I stood, the mountain split; and with much noise, from this new mouth, a fountain of liquid fire shot up many feet high, and then like a torrent rolled on directly towards us. The earth shook, at the same time that a volley of stones fell thick upon us; in an instant clouds of black smoke and ashes caused almost a total darkness; the explosions from the top of the mountain were much louder than any thunder I ever heard, and the smell of the sulphur was very offensive. My guide, alarmed, took to his heels; and I must confess that I was not at my ease. I followed close, and we ran near three miles without stopping; as the earth continued to shake under our feet, I was apprehensive of the opening of a fresh mouth which might have cut off

our retreat. I also feared that the violent explosions would detach some of the rocks off the mountain of Somma, under which we were obliged to pass; besides, the pumice-stones, falling upon us like hail, were of such a size as to cause a disagreeable sensation upon the part where they fell. After having taken breath, as the earth trembled greatly, I thought it most prudent to leave the mountain and return to my villa; where I found my family in great alarm, at the continual and violent explosions of the volcano, which shook our house to its very foundation, the doors and windows swinging upon their hinges.

'About two of the clock in the afternoon (19th) another lava forced its way out of the same place from whence came the lava last year, so that the conflagration was soon as great on this side of the mountain as on the other which I had just left.

'I observed on my way to Naples, which was in less than two hours after I had left the mountain, that the lava had actually covered three miles of the very road through which we had retreated. . . . This river of lava in the Atrio del Cavallo was sixty or seventy feet deep, and in some places near two miles broad. . . . Besides the explosions, which were very frequent, there was a continued subterranean and violent rumbling noise; which lasted five hours in the night,—supposed to arise from contact of the lava with rain-water lodged in cavities within the mountain. The whole neighbourhood was shaken violently; Portici and Naples were in the extremity of alarm; the churches were

filled; the streets were thronged with processions of saints, and various ceremonies were performed to quell the fury of the mountain.

'In the night of the 20th, the occasion became critical, the prisoners in the public jail attempted to escape, and the mob set fire to the gates of the Cardinal Archbishop because he refused to bring out the relics of St. Januarius.

'The 21st was a quieter day, but the whole violence of the eruption returned on the 22nd, at 10 a. m., with the same thundering noise, but more violent and alarming. Ashes fell in abundance in the streets of Naples, covering the housetops and balconies an inch deep. Ships at sea, twenty leagues from Naples, were covered by them.

'In the midst of these horrors, the mob, growing tumultuous and impatient, obliged the Cardinal to bring out the head of St. Januarius, and go with it in procession to the Ponte Maddalena, at the extremity of Naples, towards Vesuvius; and it is well attested here, that the eruption ceased the moment the saint came in sight of the mountain; it is true the noise ceased about that time after having lasted five hours, as it had done the preceding days.

'On the 23rd the lava still ran, but on the 24th it ceased; but smoke continued. On the 25th, a vast column of black smoke, giving out much forked lightning with thunder, in a sky quite clear except for the smoke of the volcano. On the 26th, smoke continued, but on the 27th the eruption came to an end.'

Another valuable account of the eruption of A.D. 1767 was given by Padre Della Torre, the worthy successor of Serao and Sorrentino. The account is prefaced by a useful summary of the events which happened in Vesuvius from the eruption of A.D. 1751, which he regards as the twenty-third, to that of A.D. 1766 which he entitles the twenty-sixth. His account of the grand exhibition of A.D. 1767 is interesting on account of the attempts to measure heigths, and determine temperatures and magnetic disturbances during the eruption. And it is illustrated by a very instructive and curious drawing of the great fissure in the Vesuvian cone, which gave passage to the enormous flood of lava on the 19th of October. The course of the lava is traced, among fields and houses, to its termination. (See Diagram V.)

After the great efforts of nature in A.D. 1766–67, recorded by Sir W. Hamilton, Vesuvius, we are informed by this author, was never free from smoke, nor ever many months without throwing up red-hot scoriæ, which increasing to a certain degree was usually followed by a current of liquid lava; and except in the eruption of A.D. 1777, these lavas broke out nearly from the same spot, and ran much in the same direction as that of A.D. 1767. No less than nine such eruptions were recorded between A.D. 1767 and 1779, and some of them were considerable, but the descriptions are for the most part scanty, and present few points of special interest.

A.D. 1770, March 14. The cone of Vesuvius, not much differing in height from that now in action,

opened on the south side, within a hundred yards of the summit, and gave forth lava two miles long and 2,700 paces in breadth. Again, August 10, the crater

Diagram V. Eruption of Vesuvius, Oct. 11, 1767, (*from Della Torre.*) *a.* Opening in the mountain from which lava flowed. *b.* End of current which turned toward Torre del Greco. *c.* The Canaroni. *d.* Cascade of lava into the Fosso Grande. *e.* Fosso Grande. *f.* Fosso Vetrana. *g.* End of current to Novelle. *h.* End of current toward S. Giorgio a Cremano. *i.* End of current toward Resina. *k.* Cappella di S. Vito. *l.* Casino di Berio in S. Giorgio a Cremano. *m.* Monte Somma. *n.* Slope of Vesuvius. *s.* Hermitage of San Salvatore. *t.* Casino e Territorio di D. Gennaro Vella.

itself poured out a current which injured the vineyards of Torre del Greco. This was followed by a stream from

the east side. And in December, a third flood from a very small mouth, 'one foot in diameter,' rushed into the Atrio del Cavallo [p].

A.D. 1771, May 14. A current from the side at half the height of the cone flowed toward Resina through the same fissure as that which was opened in 1767, making a cascade of sixty feet.

May 27. Lava ran toward Ottajano, as far as Mauro, and continued to run on the 6th of June. The ejected volcanic dust covered the whole mountain as white as snow.

A.D. 1773. A small cone which had formed in the centre of the crater gave vent to a current which reached the Canale del Arena. The mountain was covered with snow.

A.D. 1776, Jan. 3. The summit of the cone gave one current, and an opening in the north-west side another, through a fissure 1,000 feet long, 400 feet broad, and 60 feet deep. This fissure exposed the interior lamination of the cone.

In A.D. 1777, a great quantity of lava ran out from a point in the southern slope of Vesuvius and by the Camaldoli, near the mouths called Bocce di Voccole, from whence came the currents of 1760,—these being only 1,000 feet above the sea. Hamilton gives an excellent view of this remarkable stream [q].

For the eruption of 1779, which was singular, violent, and alarming, we are again able to rely on the graphic

[p] Annual Register, 1770.

[q] Phlegr. Fields, Supplement, Pl. i. fig. 6.

narratives of Sir W. Hamilton. His letter to Sir Joseph Banks, of date Oct. 1, 1779, contains not only an excellent history of the eruption, but many well-considered reflections, the fruit of fifty-eight ascents to the crater, and of four times as many visits to different parts of the mountain. In the month of May, 1779, during a considerable eruption, Sir W. Hamilton and Mr. Bowdler of Bath, wishing to avoid the heat and smoke which drifted toward them, followed the guide across the flowing lava,—which then was covered by a tough unyielding crust, under a load of cinders and scoriæ, very hot but not otherwise inconvenient.

They were then able to track the lava to its source, within a quarter of a mile of the summit of Vesuvius. 'The liquid and red-hot matter bubbled up violently with a hissing and crackling noise, like that which attends the playing off of an artificial firework; and by the continued splashing up of the vitrified matter, a kind of arch, or dome, was formed over the crevice from whence the lava issued: it was cracked in many parts, and appeared red-hot within, like a heated oven. This hollowed hillock might be about fifteen feet high, and the lava that ran from under it was received into a regular channel, raised upon a sort of wall of scoriæ and cinders, almost perpendicularly, of about the height of eight or ten feet, resembling much an ancient aqueduct.' (See Diagrams XVII and XVIII.)

Within the crater at this time was found a round and small actively eruptive cone; the scoriæ and ashes, which were ejected, being accompanied by loud ex-

plosions, and intolerable smell of sulphur. All this was preparatory to greater manifestations of similar disturbance in the crater, during the month of July, and to more violent convulsions in August. Watching from his villa at Pausilippo, the appearances on Vesuvius, and using a 'most excellent' telescope of Ramsden's make, Sir W. Hamilton saw the volcano most violently agitated on the 5th of August; continually throwing bursts of white vapour, which rose pile over pile to a height and bulk at least four times as great as Vesuvius. In the midst of this very white vapour, an immense quantity of stones, scoriæ, and ashes were shot up to not less than 2,000 feet: and the crater being full to the brim, gave origin to two currents of lava, one toward Somma, the other in the opposite direction toward Portici.

Ashes of a reddish hue fell so thick at Somma and Ottajano, that they darkened the air; so that objects could not be distinguished at a distance of ten feet. Long filaments of vitrified matter like spun-glass were mixed and fell with these ashes. Sir W. Hamilton informs us that a similar occurrence even more remarkable was observed in an eruption in the Isle of Bourbon, in A.D. 1766, when flexible glassy threads two or three feet long, dotted with small glassy globules, covered a tract of country six leagues from the volcano. Specimens of these capillary extensions of the vitreous masses of the lava are preserved in the Museum of Paris [r].

Among the singularities of this day's eruption was

[r] Letter to Sir J. Banks, Oct. 1, 1779.

the occurrence of an extraordinary globe of smoke of great diameter, which was distinctly perceived to issue from the crater, and proceed hastily toward the mountain of Somma, against which it struck, leaving a train of white smoke, visible for some minutes. On the 6th of August, though on the whole the fermentation in the mountain was less violent, there was a great report; the little cone fell within the crater; and two others appeared, which threw out two diverging streams of red-hot fragments. On the 7th, at midnight, the mountain fell into its second fever-fit; a summer storm (called Tropea) came on to increase the spectacle; and a fountain of red fire ascended from the crater, and illuminated the whole area to a distance of six miles from the mountain. This strange and moving picture of black stormy clouds and bright column of fire, with flashes of forked lightning, is described as being even more beautiful than alarming. It lasted only eight or ten minutes, and was followed by heavy rain.

Again in the evening of August 8, at 6 o'clock, a great smoke began to gather over the crater, a great noise was heard, and the mountain threw up showers of red-hot stones and scoriæ. At about 9 p.m. a loud report occurred, accompanied by great concussion of houses, at Portici, and in an instant a fountain of liquid transparent fire began to rise, and gradually increasing, arrived at so amazing a height as to strike every one with awful astonishment, and Sir W. Hamilton was convinced that its height above Vesuvius was not less

than three times the height of the mountain [a]. The red bright column was at every moment clouded and interrupted by puffs of very black smoke, within which

Diagram VI. VESUVIUS IN ERUPTION, August 8, 1779.
(*From Hamilton.*)

[a] In a letter from Naples, dated August 10, 1779, which is preserved in the Annual Register, the straight upward shoot of fire is said to have lasted twenty-five minutes, and then to have ceased abruptly.

electrical fire flashed freely in zigzag lines. The fiery fountain and the black accompanying cloud which was gradually collected by its side by the S. W. wind, made a marvellous picture in the clear starry sky and over the smooth mirror of the sea.

The blazing column, full ten thousand feet high, was swayed by the wind toward Ottajano: in its fall it covered the whole cone with a body of fire two miles broad. Black and ominous clouds hung almost over Naples. The Sunday-evening amusements of the gay city ceased; theatres were closed, churches opened, processions formed, women and children frantic for the appearance of St. Januarius. Suddenly the eruption ceased, and all was dark, except the glowing cinder-heaps on Vesuvius, and small lava-rills among them. 'The light diffused by this huge column of fire was so strong that the most minute objects could be discerned clearly within the compass of ten miles round the mountain. At Sorrento, twelve miles off, Mr. Morris, an English gentleman, was able to read the title-page of a book by the volcanic light.'

What Sir W. Hamilton calls the fourth fever-fit came on at 9 o'clock in the morning of August 9, in the usual manner: loud noises, violent explosions, and ejections of white vapour and black ashes:—the white vapours were piled like bales of cotton, among which the black stream rose forcibly upward. Stones in great number and of large size were thrown to great heights, directly upward, or in narrow parabolas, bursting like bombs, or flying off into a thousand fragments. About 2 p. m.

the lava broke out, and ran between Somma and the great Vesuvian cone, after which, at 7 p. m., a complete calm succeeded.

Diagram VII. VESUVIUS IN ERUPTION, August 9, 1779. (*From Hamilton.*)

The author remarks that the air this night was filled

with meteors having a nearly horizontal course,—no doubt the now well-known 'August shower' of regularly travelling cometary or star-like meteors, which had no real connection with the volcanic disturbance at Naples.

The relics of St. Januarius were exposed on the bridge of the Maddalena on the 9th, while the eruption lasted. On the 10th the mountain was quiet; but the 11th witnessed a revival of violence as early as 6 a. m. At 12 the fever was at its height, and very violent, with the same concomitants of white cloud, black ashes, and immense jets of stones and scoriæ,—a wild and weird scene, which Sir W. Hamilton imagines may have suggested the fable of the furious war between the earth-born giants and the sky-compelling Jove. The eruption ceased at 5 p. m., though smoke continued for some days, and slight explosions were heard.

Such were the scenes visible from Naples, and such the terror and amazement which they caused. Meantime the inhabitants on the opposite side of the mountain, on the northern slope of Somma, were shut out by the old crater from the sight if not from the sound and cloudy covering of its newer rival. Soon, however, they were involved in that fuliginous cloud, which on the whole drifted toward them, and were 'pelted with stones and scoriæ of lava.' The roads and fields were covered with these fragments; about Ottajano the soil was concealed by them; leaves and fruits had disappeared from the trees, which were shrunk and shrivelled with heat. Only a few days before this was a smiling and fertile

region of gay villages filled with cheerful inhabitants, expecting a good vintage and abundant fruits: now heaps of black cinders and ashes, blasted trees, ruined houses, and dismayed outcasts, attested the destructive agency of the earth-born fire. Even to distances of thirty miles, at Benevento, Foggia, and Monte Mileto, the smaller stones and scoriæ were carried in abundance, —one or two ounces in weight, while nearer the mountain masses thirty pounds in weight crushed in the roof of Caccia-bella, a hunting-seat of Neapolitan royalty, and farther off, even at Manfredonia, one hundred miles away, minute ashes fell thick. This was in the eruption of the 8th of August, and it was computed that the shower of dust had travelled one hundred miles in two hours, though the wind was not observed to be strong.

Perhaps it was at Ottajano, a town of twelve thousand inhabitants, on the north-eastern slope of Monte Somma, and three miles from the crater of Vesuvius, that the most concentrated injury and misery were seen. The sight of this place was dismal, half buried under black scoriæ and dust, all the windows toward the mountain broken, some of the houses burnt, the streets choked with ashes—in some narrow streets to the depth of four feet, so that roads had to be cut by the wretched people to get to their own doors. During the tempestuous fall of ashes, scoriæ, and stones so large as to weigh a hundred pounds, the inhabitants dared not to stir out,—even with the vain protection of pillows, tables, chairs, the tops of wine-casks, &c, on their

heads. Driven back, wounded or terrified, they retreated to cellars and arches, half stifled with heat, and dust, and sulphur, and blinded by volcanic lightning.—Through twenty-five minutes this horror lasted; then it suddenly ceased, and the people took the opportunity of quitting the country, after leaving the sick and bed-ridden in the churches. One hour more of this frightful visitation, and Ottajano would have been a buried city, like Pompeii or Herculaneum.

In A.D. 1783, the crater contained a gulf two hundred and fifty feet deep.

A.D. 1784, Oct. 12. Lava ran from the crater, and from the side of the cone opposite Monte Somma; and continued with little intermission till December 20, 1785: several streams being formed whose course was toward S. Sebastiano.

The crater began to fill up, and finally showed above its edge a new cone of eruption.

A.D. 1786, Oct. 31. From this new cone were suddenly thrown up vast quantities of scoriæ, and a stream of lava which ran four miles in six days.

A.D. 1787, July. A small stream of lava ran from the crater, into the Atrio del Cavallo, and continued to run till December 21.—On the 18th of July, Ætna was in violent eruption.

A.D. 1788, July. Small streams of lava.

A.D. 1789, September. Small streams of lava.

The energy of Vesuvius was rekindled in the beginning of A.D. 1793. In February of that year, Dr. E. Clarke went to the source of a lava stream then running,

amidst 'volleys of immense stones transparent with vitrification, and showers of ashes involved in thick sulphureous clouds.' To escape from this intolerable situation, the adventurous traveller repeated the experiment of Sir W. Hamilton, and crossed the flowing lava to the windward side. He then coasted the red stream, and 'gained the chasm through which the lava had opened itself a passage out of the mountain.' 'Out of this vast arched chasm rushed with the velocity of a flood the clear vivid torrent of lava, in perfect fusion, without scoriæ on the surface, flowing with the translucency of honey, in regular channels, and glowing with all the splendour of the sun.'

A little above the source of the lava appeared a sort of chimney, about four feet in height, from which proceeded smoke, and sometimes stones. Within the edges of the mouth of this chimney, pure sulphur was found deposited, by sublimation, while the red-hot lava was flowing at its base.

The consistence of the lava was such, even at its source, that it suffered but little depression from comparatively light bodies (5, 10, to 15 lbs.); heavy masses (60 to 80 lbs.) sank into the current and floated away with it; while a large mass (3 cwt.) let fall on the lava slowly sank into it and disappeared. The lava had a glutinous appearance, and a delusive aspect of yielding to any impression, as if it might be easily stirred with a common walking-stick, while in reality it resisted the most violent effort. Very soon after issuing from the earth it grew darker, hardened at the surface, and

became divided by innumerable cracks, and acquired the character of scoriæ. 'The same lava which at its source flowed in perfect solution, undivided and free from encumbrances of any kind, a little farther down had its surface loaded with scoriæ in such a manner that upon its arrival at the bottom of the mountain the whole current resembled nothing so much as a heap of unconnected cinders from an iron-foundry.'

Dr. Clarke ascended on other occasions, and observed carefully with a telescope, through the months of August and September. Besides the frequent explosions of red-hot stones in grand arches, amid piled-up clouds of white vapour and columns of black ashes, lava was seen flowing over the edge of the crater, or tossed up to some height and then splashed down on the surface of the cone. Thus the top was covered occasionally with red-hot stones and lava, and from the crater came up many-tinted clouds as bright as fire.

A.D. 1794. After a short period of tranquillity or comparative inaction, the mountain again became agitated, and one of the most formidable eruptions known in the history of Vesuvius began. It was in some respects unlike many others; somewhat peculiar as to the place of its outburst, the temperature of the lava, and the course of the current. Breislak, an Italian geologist, observed the characteristic phænomena with the eye of science, and his account supplies many interesting facts.

A violent earth-shock, felt at Naples, at 11 p.m. on the 12th of June, gave the signal of approaching

disaster, and induced many persons to leave their houses for the night. Quiet returned till the evening of the 15th, when about 9 p.m. the symptoms of great agitation revived. At 20 p.m. violent earthquake shocks; and a sudden outburst of lava in the Pedimentina, among the remains of earlier currents. Here a fissure was produced, 2,375 feet[t] long, and the lava

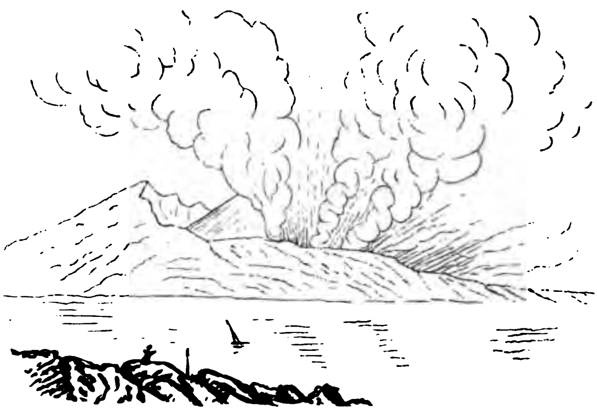


Diagram VIII. Eruption of 1794, from a comparatively low part of the mountain. (*From a Neapolitan drawing.*)

issued from a space 237 feet in breadth. The lava which erupted threw up four cones, each crateriform, (one had a double crater); and from each arose showers of red-hot stones, in such quick succession as to appear like one continuous sheet of fire in the air, with pulsations according to the variation of the expelling force.

[t] French feet.

Plate 4.

J.E.L. *J.W.L.*

PRISMATIC LAVA TORRE DEL GRECO

J.P. from Scrope *J.W.L.*

CRATER OF VESUVIUS 1822.

The showers really contained fluid or unsolidified lava, which expanded in the air like soft paste. The lava, poured from fifteen mouths, was at first united in one stream, from which occasional flashes of light arose, produced by jets of hydrogen gas, which disengaged itself from the lava, as gases expand from the surface of an ordinary fluid. Running first toward Portici and Resina, the inhabitants of Torre del Greco, while sorrowing for the probable fate of their neighbours, gave joyful thanks in the churches for their own immunity. 'Nescia mens hominum!' The lava divided, and three branches took their own wild ways. One ran 2,063 feet towards Santa Maria de Pugliano; another flowed toward Resina 3,181 feet, and the remainder passed down the valley of Malomo, toward Torre del Greco. At the chapel of Bolzano, a branch parted to the south-east, and ran 1,490 feet; the main stream rushed straight upon Torre, through several hollows, with a front of fire from 1,200 to 1,500 feet wide.

Right down the main street toward the sea, and by several winding tracks among houses and churches, flowed the destructive lava; reached the sea with a front of 1,127 feet broad and 15 feet high, and advanced into it 362 feet. The whole course from the mouth of the outlet to the end of the current in the sea was accomplished between 10 p.m. and 4 a.m., a distance of 12,961 feet. In the sea it continued to advance very slowly till the 17th. The mass of lava was measured to be from 322 to 1,111 feet broad, and 24 to 32 feet thick, except in ravines, where it is much thicker. The cubic

content has been computed to be = 1,869,627 cubic fathoms = 403,839,216 cubic feet. It is, however, usually quoted at 46,098,766 cubic feet, of which 13 millions of cubic feet entered the sea[u].

Breislak remarked some changes in the character of the earth-motions during this six hours' eruption, which led him to some particular conjectures of the cause. At the beginning the trembling was continual, and accompanied by a hollow noise, similar to that occasioned by a river falling into a subterranean cavern. The lava, at the time of its being disgorged, from the impetuous and uninterrupted manner in which it was ejected, by striking against the walls of the vent, occasioned a continual oscillation of the mountain. Toward the middle of the night this vibratory motion ceased, and was succeeded by distinct shocks. The fluid mass, diminished in quantity, now pressed less violently against the walls of the aperture, and no longer issued in a continual and gushing stream, but only at intervals, when the interior fermentation elevated the boiling matter above the mouth. About 4 a.m. the shocks began to be less numerous, and the intervals between them rendered their force and duration more perceptible.

During this tremendous eruption at the base of the Vesuvian cone, and the fearful earthquakes which accompanied it, the summit was tranquil. The sky

[u] If we take 725 feet for mean breadth, 32 feet for mean depth, and length = 12,961 feet, the content is 300,695,200 cubic feet = 1,392,107 cubic fathoms. I am not able to explain the discrepancy.

was serene, the stars brilliant, and only over Vesuvius hung a thick dark smoke-cloud, lighted up into an auroral arch by the glare of a stream of fire more than two miles long, and more than a quarter of a mile broad. The sea was calm, and reflected the red glare; while from the source of the lava came up continual jets of uprushing incandescent stones. Nearer to view, Torre del Greco in flames and clouds of black smoke, with falling houses, presented a dark and tragical foreground, heightened by the subterranean thunder of the mountain, and the groans and lamentations of fifteen thousand ruined men, women, and children.

The heavy clouds of ashes which were thrown out on this occasion, gathered in the early morning into a mighty shadow over Naples and the neighbourhood: the sun rose pale and obscure, and a long dim twilight reigned afterwards.

Such were the phænomena on the western side of Vesuvius: they were matched by others on the eastern aspect, not visible at Naples, except by reflection of the light in the atmosphere. The lava on this side flowed eastward, along a route often travelled by lava, by the broken crest of the Cognolo, and the valley of Sorienta. The extreme length to which this current reached was not less than an Italian mile. The cubic content was estimated to be half that already assigned to the western currents—taken together, they amounted to 20,744,445 cubic metres, or 2,804,440 cubic fathoms: the constitution of the lava being the same in each, both springing from one deep-seated reservoir of fluid rock.

The eruption of lava ceased on the 16th, and then followed heavy discharges of ashes; violent shocks of earthquakes; thunder and lightning in the columns of vapours and ashes; and finally heavy rains, lasting till the 3rd of July. The barometer during all the eruption was steady.

Breislak made an approximate calculation of the quantity of ashes which fell on Vesuvius during this great eruption, and states the result as equal to what would cover a circular area 6 kilometres (about 3½ English miles) in radius, and 39 centimetres (about 15 inches) in depth.

Among the notable things which attended this eruption it is recorded that in Torre del Greco metallic and other substances exposed to this current were variously affected. Silver was melted, glass became porcelain, iron swelled to four times its volume and lost its texture. Brass was decomposed, and its constituent copper crystallized in cubes and octahedral forms aggregated in beautiful branches. The zinc was sometimes turned to blende.

During the eruption, the lip of the crater toward Bosco Tre Case on the south-east, fell in, or was thrown off, and the height of that part was reduced 426 feet.

On the 17th, the sea was found in a boiling state 100 yards off the new promontory made by the lava at Torre del Greco, and no boat could remain near it on account of the melting of the pitch on her bottom.

The appearance of the promontory of prismatic lava,

which represents the advanced part of this current, may be seen in Plate IV, upper figure.

Such an occurrence is less surprising in a quiet shallow bay of the Mediterranean than it would be among the tides and currents of the English coasts.

For nearly a month after the eruption vast quantities of fine white ashes, mixed with volumes of steam, were thrown out from the crater; the clouds thus generated were condensed into heavy rain, and thus large tracts of the Vesuvian slopes were deluged with volcanic mud. It filled ravines, such as Fosso Grande, and concreted and hardened there into pumiceous tufa—a very instructive phænomenon.

Immense injury was done to the rich territory of Somma, Ottajano, and Bosco, by heavy rains, which swept along cinders, broke up the road and bridges, and overturned trees and houses for the space of fifteen days.

In January, 1799, occurred another eruption, noticed by Breislak, but the eighteenth century expired in quiet, and Vesuvius enjoyed some few years of repose.

CHAPTER IV.

VESUVIUS IN THE NINETEENTH CENTURY.

'La geologia narratrice della storia del nostro pianeta riconosce certi periodi di maggiore attività dinamica nelle forze della natura.'

PALMIERI.

A.D. 1804, July 26. Severe earthquake: diminution of springs.

August 12 to December 3. Explosion of stones and scoriæ, discharge of lava from an opening in the western side of the cone. On the 29th of August, a new opening on the southern side yielded a current of very fluid lava, which, dividing into several streams, passed near to the Camaldoli Convent, on the western side of the hill on which it is built.

A.D. 1805, August 12. An eruption of lava was witnessed by Humboldt, Guy Lussac, and Von Buch; the stream overflowed the crater on the south-east side, and ran rapidly down the cone, and reached the plain in three streams, between Torre del Greco and Torre dell' Annunziata. One branch is represented by Le Hon as reaching the sea at the Torre del Bassano, one mile and a quarter east of Torre del Greco.

A.D. 1806. On Le Hon's map of Vesuvius two currents appear, which ran down the mountain from the Fosso Bianco and the Pedimentina much in the same direction as those of 1804 and 1805. One of these reached the sea about three-quarters of a mile east of Terre del Greco.

A.D. 1809, Sept. 4. An opening on the south-east side of the crater gave a short current to the Atrio del Cavallo, where it collected like a lake of fire. Disturbances lasted the remainder of the year [a].

A.D. 1810. On the map of M. Le Hon, a short stream of lava, with this date, is represented as running from below the Piano della Ginestra, nearly in the line of one of the currents of A.D. 1767.

A.D. 1812–13–14. Teodoro Monticelli, Secretary to the Royal Academy of Naples, and Menard de la Croye, described this eruption. After the first of January, the old mouth in the crater had disappeared, and was covered by a sort of irregular vault of lava and scoriæ. Long and large crevices furrowed the interior, in which was only one small cavern below the eastern edge, with a small eruptive opening near it. Through the whole of 1812, and great part of 1813, this small opening was ignivomous, with intervals of quiet. The disturbance was considerable in May; the wells failed or were much lowered at Torre del Greco and Resina, as well as a thermal spring; and the sea retreated on the shore near Naples about fifteen or twenty paces, and then

[a] Annual Register, 1809.

returned with violence. In the latter part of May, to the east and north winds succeeded damp currents from the south and west; and in June, July, and August heavy rains occurred. Yet this did not restore the water in the wells, which still remained low and even lower than before, in September, and this scarcity was felt along the whole Vesuvian coast, and in the valley of the Sarno. To explain so general and gradually increasing an effect by assuming one sudden absorption of sea-water to the base of the volcano, appears impracticable; and the more so as it appears that before the great Calabrian earthquakes of 1783, the water failed in the hot-springs of the celebrated valley of Amsanctus.

On the 9th of August, more alarming symptoms of activity were seen in the usual ejections; which it appeared on examination came not from the old mouth, but from a new one below the other, and twice as large, being circular, and forty palms in diameter. On the 26th, stronger and higher ejections: on the 9th of October more violence, and two short-lived lava streams descended, one toward the Camaldoli, the other toward Viulo. On the 26th to the 28th, terrific noises, volcanic lightning, and a new current of lava toward Viulo. Nov. 9, the wells had begun to fill again: the disturbed and variable condition of the mountain continued. On the 25th of December, with frightful detonations, and ejections of smoke, ashes, and scoriæ, lava descended, one stream toward the Fosso Bianco, another toward Viulo. The two crateral mouths threw up clouds of matter at

intervals of six to ten seconds, or less, in vertical or inclined directions, some considerable masses occupying eight, ten, twelve seconds in falling. The area covered by the ashes was in a radiating form, Vesuvius being the centre, and Torre del Greco and Portici included in an arc of about 60°. On the Roman road they lay six or seven inches deep; containing several lumps of lava weighing ten ounces; one measuring above five inches in diameter. Through January, 1814, the usual ammoniacal and other muriates were collected; and in April, Monticelli found with surprise, in the same situations, no longer any chlorine in combination, but sulphuric acid, gypsum, and sulphur; while lava which had issued on the 9th of October, was found covered by specular iron (ferro oligisto). Slight occurrences of this eruption were really not quite ended before the close of 1814.

A.D. 1816, August 7. Eruption of half a day; a shock, and two flaming currents, one toward Mauro, the other toward Camaldoli.

A.D. 1817, Dec. 22. Lava issued from two small cones which had been formed in the crater since 1813; one of the streams ran toward the Camaldoli, the other to Bosco del Mauro.

A.D. 1818–19–20–21. In all these years the mountain was disturbed. April 17 and November 25 are specially noted for eruptions of ashes, but not of lava. Sir H. Davy arrived in Naples in December, 1819, and remained till February, 1820. A small eruption had taken place before he visited the mountain, and

a stream of lava was then flowing with considerable activity from an aperture a little below the crater, which was throwing up stones every two or three minutes. On its issuing from the mountain, it was perfectly fluid and nearly white-hot; its surface appeared to be in violent agitation, from the bursting

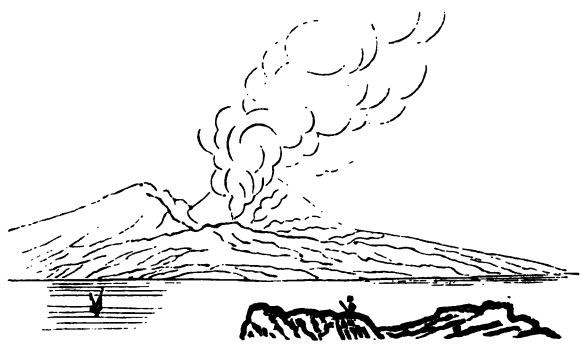


Diagram IX. ERUPTION OF LAVA, December 19, 1820.
(*From a Neapolitan drawing.*)

of numerous bubbles, which emitted clouds of white smoke. The gas disengaged from the lava was common air: the white vapours were pure salt, in a current of nitrogen with 9 per cent. of oxygen.

In April, 1820, several openings (six on the north-west side) sent lava to the Fosso della Vetrana. In December of this year a considerable eruption on the north-west flank is represented in a coloured drawing, as running down the cone, and then sweeping round to the Pedimentina. And in A.D. 1821, another drawing shows

the summit widened, very much broken, and highest on the south edge [b].

Early in A.D. 1822 the wells lost their water. The beginning of the eruption was in February; on the 23rd and 24th of this month, lava flowed into the Atrio del Cavallo, from an opening near the six mouths, in a line

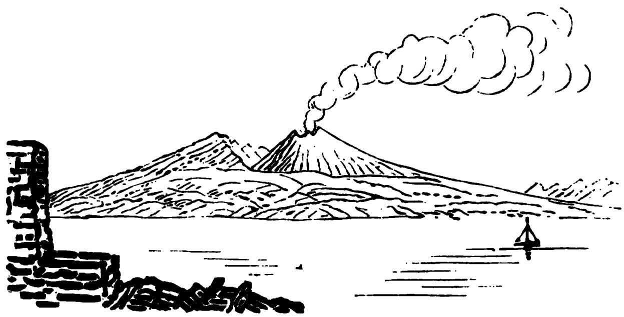


Diagram X. ERUPTION OF ASHES, 1821. (*From a Neapolitan drawing.*) The cone is seen to be truncated and uneven, the southern border being the highest.

north-west of the summit, which in April, 1820, gave a current to the Fosso della Vetrana. 'On the 23rd of October, the great cone suddenly fell in with a loud crash [c].' Two streams of lava issued from the crater; one expanded on the Pedimentina, and then turned south-eastward toward Bosco Reale, which it approached within a mile; another, forming a large pool in the Piano della Ginestra on the western part of the

[b] For the opportunity of examining these drawings I am indebted to the Rev. E. Fox, M.A., formerly of New College, Oxford.

[c] Murray's Handbook for Naples.

mountain, ran down in several branches to within a mile of Resina: another stream ran toward Torre del Greco.

Mr. Scrope, who witnessed this eruption in October, 1822, presents a sketch of the appearance of Vesuvius as seen from Naples: the main feature of which is a huge vertical column of white clouds heaped, like vast fleeces of wool, to four or five times the height of the mountain, and then expanding to some miles in breadth. Enormous jets and falling streams of black ashes accompanied the cloud-column; lightnings played about its sides, and the gleam of volcanic fire reddened its base.

Grey ashes and black sand were spread thickly over all the surrounding country; heavy rain fell from the volcanic clouds; the ashes agglutinated by this rain formed thin tufa beds. At intervals large masses of lava were thrown to considerable distances: one mass, many tons in weight, was found in the gardens of the Caserta of the Prince of Ottajano, about three miles from the summit of Vesuvius, on the south-east side.

After the eruption, the mountain was found greatly changed in aspect: the Vesuvian cone was lost; a huge deep crater three miles in circumference, with steep interior faces, occupied its place, and was partially filled by vapour of water mixed with hydrosulphuric and hydrochloric acids. The depth of the cavity was found by Mr. Babbage to be 938 feet below the highest part of the crateral edge, and this edge was reduced from being higher than Monte Somma to 300 or 400 feet below the summit of that ancient mountain.

Dr. Daubeny, who visited Vesuvius in 1824, after the

mountain had regained its tranquillity, found the interior of the crater much as above described, and still filled with steam and acid vapours.

In the course of 1828, 1829, 1830, 1831, the cavity was gradually filled by loose materials thrown up from the centre and falling down from the sides, so that a small cone appeared, 150 feet high above the edge of the crater. Lava currents issued from the cone in 1831, 1832, 1833.

A.D. 1828, March 14. Rent on the south-east side of the crater. Smoke—ashes—lava. On the 22nd a lava stream from the rent ran round the base of the cone, to the Atrio del Cavallo. Showers of stones from the crater.

A.D. 1830, Aug. 18. Mentioned in the work of Dr. Daubeny on Volcanos, 2nd ed. p. 291.

A.D. 1831, Sept. 18–1832, Feb. Within the crater, a small central cone had gradually formed till it was 150 feet above the rim, the crater being full. On the 18th of September, a stream of lava was thrown out of this cone, which ran south-eastward, toward Bosco Reale.

Dec. 25. A stream of lava ran toward Resina. Other streams followed till February, 1832.

A.D. 1833, August. Water failed in the wells: on the 13th, three streams of lava descended toward Torre del Greco, each subdivided in its course.

A.D. 1834, August. An eruption began which may be regarded as the concluding act of the series of volcanic efforts since 1831. After that date two conical masses had been accumulated in the middle of the great crater, one of them 200 feet high. On the 22nd of August

one of them ejected stones and scoriæ. On the 23rd a current of lava started from the foot of the great cone on its western side, and then bending toward the Crocella, reached the foot of the rising ground called the Cantaroni, and the path which led to the Hermitage. The two hillocks fell in on the 24th. Then a new opening appeared on the eastern side, and lava flowed in several directions. One stream ran to the Atrio del Cavallo; another to Caposecchi, a village of five hundred houses, which were all overwhelmed except four. This current was said to be half-a-mile broad, and from 15 to 18 feet deep, and to have been flowing eight days. A smaller branch is marked on Le Hon's map, as running south-eastward to near Bosco Reale. Like the currents of A.D. 1751, 1754, and 1822, the stream of 1834 threatened Pompeii with a new visitation. Clouds of volcanic black sand accompanied the moving lava, and gave out electric flashes. Hydrogen flames, according to Abich, were observed. Fishes and oysters perished in ponds at Pozzuoli, and in Lakes Fusaro and Licola near Cumæ. Torrents of hot water flowed on the 28th of August. Hard lava, at a temperature of 390° F. near the surface, emitted from fissures much aqueous vapour impregnated with free muriatic acid, and muriate of ammonia coloured by iron.

After this eruption, which lasted twenty-nine days, the cone referred to as being formed before A.D. 1831 was found to have disappeared, and the floor of the crater sunk down into a double abyss, divided by a narrow ridge of lava. This account is chiefly from

Dr. Daubeny's communication to the Royal Society (Phil. Trans. 1835) embodying the observations of Monticelli.

A.D 1838, March 6. Streams of lava, descending slowly and filling valleys on the slope of the mountain.

A.D. 1839, January. Two streams overflowed the crater; one ran westward to the Fosso Grande, the other toward Ottajano. Ejection from the crater of lapilli and black sand, composed of augite and tourmaline, which fell on Torre del Greco and Torre dell' Annunziata. The crater now became a funnel 300 feet deep, which was accessible to the bottom.

A.D. 1841. The continuing disturbance restored a central cone in the crater like that of 1831; ejecting lava and stones: in four years it was visible from Naples.

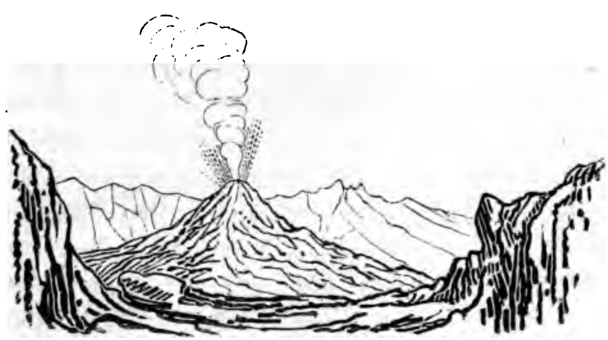


Diagram XI. INTERIOR OF VESUVIUS, showing the Cone which grew up in A.D. 1845.

A.D. 1845. In this year the great hollow top of the mountain, whose precipitous edge was not much higher

than the top of Somma, was disturbed by considerable ejections from a steep cone, growing up in the middle.

April 22. A small current flowed on this occasion from the base of the small central cone; and was remarkable for containing crystals of leucite, a mineral rarely found among modern Vesuvian products, though common in the older accumulations of Somma.

A.D. 1847, Nov. 13. The great crater overflowed on several sides, and lava ran in three directions, eastward toward Ottajano, south-eastward toward Bosco Reale, and westward toward Torre del Greco.

A.D. 1848, June. The volcano was active.

A.D. 1849, December. Frequent eruptions of lava containing crystals of leucite.

A.D. 1850, Feb. 6, to end of month. The central cone of 1845, composed of scoriæ, was 70 feet higher than the Punta del Palo (on the edge of the crater), and had an interior cavity 100 feet deep. Feb. 7, the cone opened and gave origin to three streams, two running toward Ottajano, the third toward Bosco Reale. Advancing in a broad stream toward this village, it destroyed a wood of oak, ilex, and ash; closely enveloping the stems, which blazed and steamed under the conflagration, and were tossed up 10 to 20 feet. Great eruptions of red-hot stones from the crater accompanied this lava-flow, and they fell in showers over all the mountain. The mountain was changed in form; the old walls broken down; the central cone reduced. The crater finally exhibited was supposed

to be about two miles in circumference, and 150 feet deep.

In January, 1855, after great earthquakes, a large fissure opened on the north slope of the great cone, and on the 1st of May gave forth from ten mouths on this line a stream of lava of remarkable fluidity; which descended into the Atrio, and flowed along the fissures at the western extremity of this hollow, and north of the Observatory, in a long narrow course to Massa di Somma, and almost to La Cercola, while a still narrower branch ran westward toward S. Giorgio a Cremano. Chloride of lead was among the substances 'sublimed' in the fissures of this great current after the eruption. Its course of six miles, marked by the hollows of old fissures, had been already traced by the current of 1784. This is the longest stream of lava which has passed in the north-western direction, and was in motion for twenty-eight days[d].

Since 1855, the mountain had undergone the usual changes of the crater, by degradation of the sides, so that it was nearly filled, and two small cones appeared within the space; which gave passage to much vapour, ashes, and lava.

A.D. 1858. Following the great earthquakes, which did so much damage in Southern Italy, an eruption began on the 21st of May, and in the course of it seven new mouths opened, yielding lava in broad streams and splendid cascades, rushing over forests,

[d] See M. De Ville, Comptes rendus, June, July, 1855, and Rev. A. S. Farrar, British Association Reports, 1855.

vineyards, and homesteads. The openings were on the north and north-west sides of the cone, and the streams flowed in different directions; one great stream ran toward the Hermitage, and entering the valleys on each side wound round the hill on which it stands like a fiery serpent; a second stream tended toward Pompeii: and another is said to have 'followed the course of the very stream which destroyed Herculaneum,' and to have menaced Resina with a similar fate. This last current started from three mouths, a quarter of a mile distant from the main cone; it was fed by intermitting puffs and pumpings, and became a flood 750 feet wide, the top covered as if by glowing coke, which made a fearful noise as it rolled grinding and crashing along. The crater fell in while Cozzolino the guide was looking at it, and lost 200 feet of height. He described it as swaying, yielding, and falling[e].

A writer in the Annual Register describes the lava streams and cascades thus: 'Vesuvius is girdled with fire, and from this girdle seem to drop down jewels of the utmost brilliancy.'

A.D. 1860. On the great national map which includes Vesuvius, two short streams of lava are marked with this date, as running from the Piano della Ginestra, between the currents of 1794 and those of 1858. The origin of these streams is near that of the great flow of 1794.

After this date the crater was again nearly filled, but still gave out vapour and ashes.

[e] Annual Register, 1858.

A.D. 1861, Dec. 8. After severe earthquakes, eleven small cones, less than half a mile above Torre del Greco, ranged on a fissure 2000 yards in length, at a lower level than those of 1794, threw out clouds of ashes, one of them giving vent to lava. The town was shaken to pieces, the ground fissured in all directions; carbonic acid gas and carburetted hydrogen came up from the fissures. The adjoining sea-coast was raised 3½ feet English.

From this time to the present Vesuvius has rarely been quite at rest.

In 1865, 1866, 1867, earthquakes were prevalent in Southern Europe and the north of Africa; next followed the eruptions of Ætna and Vesuvius, Santorino, the Azores, and Hecla. To these we must add the great outflow of the Hawaian volcano, in April, 1868, lately matched by the dreadful earthquake of the coast of Central America. Vesuvius, now in reality rarely quite at rest, answered promptly to the earth-tremors of the autumn. Even as early as the 10th of February, 1865, there appeared, in the depth of the crater left by the previous eruption, a small opening (boçca) from which issued, with great force to a great height, portions of incandescent lava, which fell in and around the crater, and added to its ashy envelope. There was snow on the mountain, from which a vapoury column rose, while stones came rolling dangerously down the slope. Explosions were frequent, and the cloudy ejections abundant for some days: the force was then reduced; the materials gathered in a conical heap, within the crater;

lava afterwards came out in small streams quickly concreted, so as to have but a short flow; and thus by alternate additions of ashes and lava, the little cone grew up, till its energy was spent before it filled the whole crateral abyss.

In March, 1865, the summit was dangerous to approach from the multitude of red-hot stones and ashes thrown out, and this continued till May, with the usual effect of once more filling the great crateral cone. In May, the crater, 900 yards round, emitted aqueous vapour and hydrochloric acid gas[f].

A.D. 1867–68. The history of the eruption which is still in one phase of its progress (October, 1868) has been given in the 'Athenæum' and other contemporary journals by resident witnesses, and conclusions of moment regarding it have been presented by Professor Palmieri[g]. It endured through the winter of 1867–68, and after several times losing activity, has burst up with new energy.

In October, 1867, the little cone was in silent repose, except when the fumaroli gave out vapours. Toward the end of this month, the seismograph, with its electro-magnetic apparatus for registration,—which is erected at the Observatory of San Salvatore, 2,000 feet up the mountain,—gave indications of local subterranean shocks. From the 8th to the 12th of November, it was evident that the ground was in continual agitation, and the magnetic needles oscillated both vertically and horizontally.

[f] Murray's Handbook for Naples.

[g] Sull' Incendio Vesuviano del 1867–68. Trans. Roy. Acad. of Phys. and Math. Sci., Naples, April 11, 1868.

In the nights of the 12th and 13th of November, the fires were rekindled on the spot where they had ceased. On the morning of the 15th, over this mouth there appeared a small cone surrounded by four other lesser cones; apparently an elevatory action had occurred, which had thrust outwards the concreted masses of the eruptive cone already mentioned. On this account the new cone appeared formed of great, nearly vertical prisms, stony and compact in texture, like the basalts and dykes of Monte Somma. These prismatic masses were in fact displaced portions of horizontal sheets of lava, which had been deposited in the old crater during the preceding eruption. Through the fissures thus made, lava streams came up and at last filled the old crater, all the upper plateau of the Vesuvian cone being fissured in lines directed toward the apex of the new cone.

This new cone, formed in great part of large masses of compact lava, uplifted by the fresh currents, was afterwards covered by so great a quantity of new ejections, that in a few days it had risen to a height of 120 metres = 392 feet, and overspread not only all the edge of the old crater, of which only traces remained, but the whole terrace-like space of the Vesuvian summit. The four small eruption-cones already noted were covered up and buried in this new and rapid growth; but it appeared that, within the new cone, four spiracles represented them, from which lava fragments were tossed up, which gave at night the aspect of eruption-vents. By frequent ejections from these vents, either simultaneous or successive, the mass of the cone was continually aug-

mented, and the openings were expanded. The ejections of scoriæ were accompanied by bellowings (boati), which were occasionally heard at Naples, and nobly re-echoed in the Atrio under Somma. After each detonation globes of white vapour were formed, partly tinted red or yellow. The vapour was often black with sand, lapilli, and cinders, thrown out from the cone, which was covered by the fallen masses. The greatest height to which they were thrown was about 300 metres = 984 feet. The new cone grew rapidly in height; it became split on the western side, when the eruption slackened; but the breach was repaired by new materials.

As already stated, lava flowing from the new cone had in a few days filled the whole crateral area of Vesuvius to the brim; the fluid mass then began to pour over the edge, now in one direction, then in another; so that, when at its widest expansion, the whole cone from south to west was glowing with fire, above the vineyards of Torre del Greco. The issues of lava were observed by Palmieri to have a daily period of two maxima and two minima, and the eruption-cone to throw up twice a day its dusty columns with more than average force; these accessions of violence corresponded with the times of maximum. The hours of maximum and minimum were observed to be later from day to day: circumstances in which a likeness to tidal phænomena can be traced. Moreover, it appeared to Palmieri, that the eruptions were sensibly strengthened at the syzigies, and weakened at the quadratures of the moon.

The lava courses in November and December, 1867, and January, 1868, were not long: the most considerable being in two directions, one toward the south-east boundary of the Atrio, called the Cognolo di Bosco, the other and longer one down the cone in two streams, one toward the Crocella, at the end of the ridge of the Observatory, and the other toward the Piano della Ginestra. These two streaks of fire running down the cone, in cascades, had one elevated origin; but after some time and partial cessation, there was the appearance of an eruption from the base of the cone. This arose from the penetration of solidified lava by fresh currents, which forced for themselves a new exit.

Such is a collected view of the early course of the eruption, subject to great inequalities and pauses. From the 20th of November, through the first half of December, 1867, thunderings were heard as far off as Capri, eruptions of ashes were violent, and lava flowed abundantly, so that in this period, previous to the 14th of December, there were at times thirteen streams of lava issuing from various points, and pouring down the sides of the mountain. The upper part of the cone was perforated like a sieve, through the holes of which the lava kept gushing out. The currents swept on through the snow, interlining the brilliant white mantle of Vesuvius with black, and at some points falling over precipices like cascades[h]. Similar appearances continued to the 7th of January, 1868; and were witnessed by

[h] H. W. in Athenæum, dated Naples, January 7, 1868.

hundreds by day and by night on the mountain, and by thousands at Naples. The ascent to the crater was rarely practicable, on account of the continual changes of the surface and the frequent projection of showers of heavy stones.

After a short pause, the mountain again became active. On the 20th and 21st of January, earthquakes and thunderings were felt and heard at Naples, and lava made its re-appearance. The instruments at the Observatory participated in the movements, and on the 26th the currents of lava overflowed the top of the mountain, and slowly and silently covered all the western side with a grand robe of living fire, extending from the summit to the Piano della Ginestra above the cultivated grounds of Torre del Greco. (In the night of the 26th occurred the destructive land-slip at Santa Lucia, on the Chiaja of Naples.)

Effects of the same general character continued, with intermissions, through February, but no great manifestations re-appeared till after the early days of March. In this month, from the 8th to the 12th, the instruments at the Observatory were again rudely shaken; the ashy eruptions from the summit were violent, rising to 1,000 and even sometimes to 1,600 feet; and on the 11th the mountain cone split from top to bottom on the south-east or Pompeian side, and began to give out a broad complicated mass of rough slaggy lava, visible from Pompeii, at the edge of the old crater line continued from Somma. The quarter of most activity seemed thus to be removed from the side of Torre del

Greco, and in fact, though there was a stream of lava, which flowed toward the Crocella, and divided into three branches, the main force of the eruption was concentrated on the summit and the back of the mountain, looking from Naples. So regarded at night the sight is described as more wonderful and dazzling than anything seen since November. 'The mountain appeared to be bursting with subterranean energy—the entire summit was on fire—the blackened walls became red with heat, and while the lava surged, not flowed, over, as angry waves do over a sandy bar, heavy stones, which the eye could select and measure, were thrown up to the height of 1,600 feet[1].'

We arrived in Naples on the 16th of March, during a lull of the volcanic excitement, when the prevalent expectation was that the mountain was relapsing into its ordinary state of troubled repose. Light vapours were rising from the summit, as we approached toward the graceful blue dome from Capua, and heavier clouds hung about it when we entered Naples. For some days this was the aspect of affairs, and we found it desirable to occupy ourselves with objects of interest at Pompeii and Pozzuoli, Agnano and the Solfatara; and to visit the University Museum on a rainy day. But on the 21st, with a high barometer and fine weather, we took our seats for Pompeii, and prepared to ascend the mountain on that side where the fumaroli were in action some days previously.

[1] Athenæum. H. W. in a letter dated Naples, March 21, 1868.

The two aspects of the mountain, that from the west with the high ridge of Somma on the left of Vesuvius,

Diagram XII. Vesuvius from the West. (*Original.*)

and that from the south showing the younger mountain almost entirely in front of the older, suggest

Diagram XIII. Vesuvius from the South. (*Original.*)

to explorers the two best and most instructive routes for ascent: from Resina on the west, and from Pompeii on the south. At either point we begin from ruined cities: Herculaneum lies 'fathoms deep,' below the streets of Resina, and we tread upon its unknown treasures; Pompeii has been brought again to daylight; both destroyed and buried below heaps of mud and ashes in the first recorded eruption, A.D. 79.

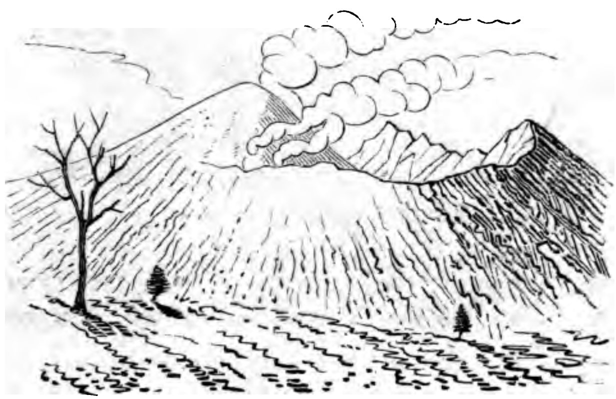


Diagram XIV. VESUVIUS FROM POMPEII, March 18, 1868. (*Original.*)

We made the ascent from Pompeii, under favourable circumstances, as far as the broken crateral edge of Somma in its continuation south-westward toward the Pedimentina. It was a calm and pleasant day; two or three lava-currents which had started from this side of the base of the cone, and had been in full action the previous day and night, were now in their dying

struggles; considerable puffs of vapour were rising at various points from fissures across the rather wide field of hot scoriaceous lava, but no black jets of ashes made their appearance anywhere.

Diagram XV. ASCENT OF VESUVIUS FROM POMPEII, March 21, 1868. (*Original.*)

Setting forth under these inviting circumstances, with intelligent and strong-limbed Raffaelo del Sarno, and a troop of supernumeraries, our course lay across the easy cultivated slopes, and through the scattered villages called Bosco Tre Case. The steeper ascent began among undulated old lava-currents, and dark ashes interspersed with vines and lupines,—here and there an old crater-like cavity,—then up among the desert slopes of dark dusty hollows, and long narrow winding crests of old

streams of lava, often rugged at the surface, but generally smoothed over by the showers of dry lapilli. Red bands and streaks occur among the lava-currents, and the whole stream stops in some cases abruptly.

Diagram XVI. LAVA STREAMS IN THE ASCENT FROM POMPEII. (*Original.*)

Passing by fissures from which bursts of steam rise at several points (fissures made by a late earthquake across the lava), ascending obliquely, we reach a broad hot region, in which are the principal fumaroli: from these quite lately—last night—lava was flowing freely, now barely moving under a solid coat of pipy or cellular rock, deep sunk below the rest of the surface, or merely glowing in deep cavities, and yielding reluctantly to the pressure of a pole, which instantly takes fire.

Beneath our feet, however, for considerable spaces, the

ground is really fluid, only crusted over by the partially coherent and very partially cooled scoriaceous blocks. Removing these, where practicable, by the help of a pole, we see the sullen red lava below. The quickness

Diagram XVII. Deserted Tunnel of Lava, and Open Canal below it. (*Original.*)

of the consolidation of the surface of lava is remarkable; we stand on the solid crust, over what remains of yesterday's current, in a deep canal, which not long since ran full of melted rock; on this very hot surface it is requisite to keep in motion, if one has any regard for English shoes, but there is no other inconvenience. The air is hot, somewhat like that in the vicinity of iron furnaces — which seems, whether it be so or

not, a little deficient in oxygen, but no smell of sulphur, in any combination, and no fumes of hydrochloric acid.

Examining with care these hollow canals, or tunnels, overarched with lava sheets, we find sublimed salts, especially ammoniac and sodic chlorides, with free

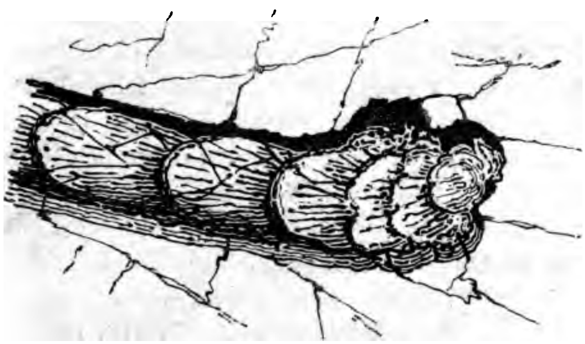


Diagram XVIII. Canal in which Lava is in the last stage of motion above Pompeii. (*Original.*)

sulphur. The crust formed over the lava in these channels is remarkably 'pipy' as well as 'cellular,' the pipes being in fact cells 'drawn out' by the current. Very much such pipes appear in some metamorphic rocks about Caer Caradoc and Bootle,but in the latter case they are filled with agatized silica.

The height of these curious appearances near the source of the recent jets of lava, is about 2,760 feet above the sea.

In the evening of the 21st of March, 1868, after an

interval of unquiet repose, during which by day wreaths of vapour rose from the summit, Vesuvius rekindled his watch-fires, and began to blaze at intervals much like an iron-furnace in the north of England, and, like that, occasionally lighting up the clouds above, while a broad glare of red reflection spread over the sea in front. It was bright starlight, and one serene star on the left of the crater gave its pure rays in contrast with the ruddy glow. Not unmindful of the chance of seeing such a phænomenon, we had selected before leaving England a very perfect telescope by Cooke, with an aperture of 1·5 inch, and a range of excellent powers from 25 to 50. Using the lowest power, the blaze was seen to be a mass of red-hot or white-hot fragments, many of them quite clearly visible as single well-defined projectiles whose curves were all traceable exactly—the rise and fall determinable with precision. Our station was on the terrace-top of the Hotel de Russie.

In general the course of the parabolic curves was in all directions from the vertical, but sometimes a jet of many bombs rose upright like a hundred contemporaneous pyrotechnic stars, only that the latter break and scatter more than the fireworks of Vesuvius. While contemplating for some time this rise and fall of the crater-light, and trying its rate of pulsation, it occurred to an American gentleman, Mr. Vail, to whom we were indebted for an interesting sketch of lava-currents seen under very favourable circumstances, to note in the field of the telescope the apparent length

of the ascent of the bright Vesuvian bombs compared with the diameter of the field of view. This was done often, and the jets evidently occupied one-fourth, one-third, one-half, to three-fourths of the field—this was

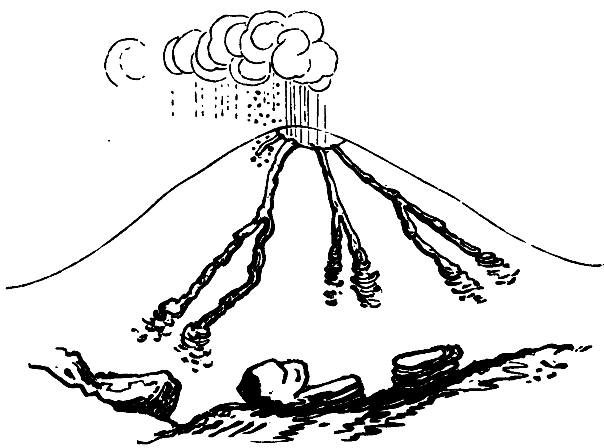


Diagram XIX. LAVA STREAMS ON THE NORTH SIDE OF VESUVIUS, DESCENDING TOWARD THE ATRIO DEL CAVALLO. (*Original.*)

clearly and certainly traceable. I have carefully determined the angular value of the field to be $\frac{1}{40}$ of the distance: therefore the utmost height to which the bombs rose, or rather to which the more conspicuous were traceable, subtended an angle of $1^\circ\ 3'$. The distance from the Hotel to Vesuvius may be taken at eight miles. From these data the elevation of the bright masses of ejected lava and stones above the summit of Vesuvius appears to have been at most 760 feet.

Mr. Lee and myself then, by counting pulsations, made other trials, and found on the average about 5″ to be consumed during the fall, and in extreme cases, 7″. The former gives 400 feet, the latter less than 800 feet. Sir W. Hamilton records an observation of 11″ as the time which elapsed during the fall of a stone shot upward from the summit, and this gives something less than 2,000 feet for the vertical range, no allowance being made for the general effect of the uprushing current in retarding the descent.

During the exhibition, in its many lulls and bursts, the rugged edge of the crater was sharply visible in the telescope, and the eruption seemed at intervals to occupy its whole breadth, which was about equal to the height of an ordinary outburst of the red flame. The intervals of action and repose were irregular; as small as 10″ and as large as 30″ or more. That lava was flowing down the northern side of the cone from the crater was apparent by the bright narrow trembling line, with occasional puffs, which was visible on the outline of the cone for some hundreds of feet below the top.

These splendid effects were repeated in the evening of the 22nd of March. As the darkness grew, the fireworks shone out not only on the summit of Vesuvius, but also on the slope, toward Somma. The whole of the outline of Somma fronting Vesuvius, as well as the northern outline of the cone itself, was plain against the illuminated vaporous atmosphere, and it appeared certain that lava was flowing down to the Atrio del Cavallo.

Stones bright as stars, of a reddish hue, were projected by hundreds from the upper, middle, and lower of these craters or mouths, in one stream directed to the north from the summit of Vesuvius. Time of falling not exceeding 7″, nearly equal to 800 feet.

Another grand effort came under our notice in the evening of the 26th of March. At this time the sky was extremely dark; the old mountain of Somma was lighted up by the fires of its younger rival, down whose side flowed, bright and red, one long straight line of liquid fire, on which we gazed long and earnestly with the telescope. The effect may be imagined by examining Plate V, and observing that only the upper vent threw out stones in abundance, to about 800 feet, and they fell in showers all round, even to the opposite side of the cone, and were seen glittering like stars on the ground: separate bright red stars they seemed, being really lava lumps of considerable size[k].

One more look at the evening lights of Vesuvius—the 27th of March—the grandest of all the exhibitions. What a spectacle! One long burning stream down the whole north-western slope of the great cone, quite reaching into and spreading across the Atrio del Cavallo. On the top, fitful bursts of clouds of fiery bombs and wide-spread ashes; below just where it appeared last night, but now far brighter, and glowing with a full

[k] These appearances were distinctly seen,—the masses were seen to fall and be flattened on the ground,—from the apartments of that noble lady-representative of English science, Mrs. Somerville, on the Riviera di Chiaja.

steady eye of light, the second great burst of light and motion. Now it spreads a bright cloud above; then down to the valley knots and lines, sometimes double, of sharp white or reddish fire, swelling into considerable masses, and broken into many gleaming points. Toward the base a wide cataract of fire is pouring toward us, and is stretching its red fingers over the older lava. Now and then a star-like point in advance seems to beckon onward,—

'den freien tochter der natur.'

Finally, in the deepest part of the visible horizon, a horizontal row of fourteen small bright star- or gem-like fires marks the conquest of the current over the flat space of the Atrio, and seems to unite again the long separated masses of Somma and Vesuvius,—parent and child, the far-descended progeny of the struggling Titan. (Pl. V.)

In some respects the ascent from Pompeii is more instructive than that from Resina; in other particulars the other has the advantage: both should be undertaken. The very first step at Pompeii shows us the ashes and cinders which overwhelmed that city, and, if we mistake not, the slaggy lava and accumulations from eruptions of earlier date on which Pompeii was founded. In one of these places, where the slaggy cellular mass and its ashy accompaniments seemed to have been cut into by the walls of a house, we found leucite crystals by hundreds.

In the ascent the black sand which lay so thick between the snaky ridges of lava, attracted our at-

VESUVIUS AT NIGHT.

tention, and we took enough of it for examination. It contains crystallized hornblende, black and brilliant, with olivine, and 'fer oligiste,' attractible by the magnet. One of the *old* lava currents on this side of the mountain, which ran down to Bosco Reale, is a solid gray rock, which has been quarried, and contains fine crystals of pyroxene.

On the other hand, in the Resina route we have first the 'bombs' in the vineyards rich in crystals; the vast black floods of lava poured forth in 1855, 1858, and 1861; the ejected blocks in the Atrio; the frowning crags of Somma, and the rough channelled sides of Vesuvius, down which so many currents have descended into the hollows below.

Starting from Resina with Cozzolino, the excellent descendant and representative of a still more famous guide, we pass among extensive gardens and vineyards, along a roughly-paved road, which in heavy rains becomes a rivulet or a torrent, and emerge on the sterile domain of lava. All the rich soil in which the vines are deeply planted is composed of volcanic sand, crystals, scoriæ, and bombs, thrown out by many eruptions, especially the great outburst of 1631. These bombs are not like those of Auvergne, which were liquid while flying through the air; but rather appear to have been torn off from solid rock, and thrown out with little change. Cozzolino stops his horse, to break some of these bombs, and to prove that in them are found many of the most beautiful and valued minerals of Vesuvius: they are probably parts of rocks older than any part of it,

portions of the roots of ancient Somma, or of plutonic products earlier than Somma.

The first view of modern lava lying in heapy ridges, full of hills and hollows, on the sloping sides of a volcanic mountain, must be very surprising to one who draws his ideas of the probable aspect of the phænomenon from the columnar Giant's Causeway, the dykes in Arran, the toadstone in Derbyshire, or the whinsill of Teesdale. In all these cases of interposition, the solid well and uniformly crystallized 'trap' is as much unlike to the cellular gray or black, rusty or pitchy-looking substance before us, as the parallel masses of greenstone are to the confused, arched, contorted, and even twisted aggregates of the lava of 1858. There it is in its great dark broad irregular masses, cracked across in several directions, and still giving up vapours, when rain or snow enters these fissures. This prodigious mass of slaggy lava which fills the Fosso Grande on the left, and rises in a high broad tract on the right, came from openings near where the north foot of Vesuvius is planted on the Piano, which is margined by the depressed western edge of the old crater of Somma. These openings extended over a space about three-quarters of a mile in length, and the lava ran about two miles, being in all its course south of the ridge of San Salvatore, which is mainly composed of tufa, and is a part of ancient Somma.

By this amazing outflow the old road to the Hermitage, which was passable by carriages, was wholly stopped, and only a winding but very fair horsepath,

made with some trouble across the intractable lava, leads to that rather poor place of hospitable refuge. It is, however, a glorious ride, with distant prospects of surpassing beauty, especially toward Ischia and Capri, and many objects of closer and nearer interest, such as the trees carbonized in lava, the ropy streams, and cake-like terminations of the currents, amidst flowery turf or ruined vineyards—strange and affecting contrast.

Onward, keeping the summit of the threatened narrow ridge of the Observatory, threatened by almost every fresh eruption, we reach a second great stream of lava, that of A.D. 1855, one of the longest upon record,—one of the most fluid,—which sprang out of the side of the cone of Vesuvius, at above half its height, above the hollow in which we now are between the two mountain masses. The course of this remarkable current is all before us, from its high birthplace all along the shadowy valley which we have entered; then by the deep glen on the north of the Observatory; and afterwards in two streams parting at an angle of 60°, each occupying an ancient fissure, till at five miles from the origin each came to an end, a long way down the north-western slope of the mountain. After riding for a great distance, with some successions, across its many ridges and hollows, and frequently gazing upwards to the points of efflux of this and several other currents, we quit our steeds, in the Atrio rightly named del Cavallo, and face the steep and unstable slope of ashes and scoriæ which compose the mass of the great eruptive cone of Vesuvius.

The Atrio del Cavallo is the central part of a crescent-formed valley, left between the cliffs of lava and consolidated ashes which compose the semicircular ridge of Somma and the protuberant northern base of the dome of Vesuvius. The whole crescent is about three miles in length, widest at the north-west end, where it joins

Diagram XX. VOLCANIC STRATA IN THE PRECIPICES OF MONTE SOMMA, 868. (*Original.*)

the valley north of the Observatory, and opens into the glen of Massa Somma, and narrowest at the south-east end, where, under the name of Canale del Inferno, it opens into another glen leading toward Bosco Reale. The Atrio (using this term for the whole crescent), usually narrow at the base, is in many parts, especially toward

the east, a good deal filled by loose blocks ejected, like huge bombs, from Vesuvius in A.D. 1822, and both toward the north-east and south-east much filled by rugged portions of the many lava streams which have gone out of it in those directions. In one place nearly north from the summit of Vesuvius, a little flat space appeared in March, 1868, which was uniformly wet and rather muddy, like a lake nearly dried up.

Under ordinary circumstances, the ascent from the Atrio to the summit edge of the crater of Vesuvius presents no other difficulty than that of fatigue in wading up the loose and backsliding slope. But on the occasion when Mr. Lee and myself examined the one grand lava-current which came streaming down from the crater-edge, and set its foot far into the Atrio, we were prevented from ascending to the source of the current by the frequent ejection of showers of stones of various sizes, which, by actual impact from above, or by rolling down the slopes, created considerable danger. Besides this, after we had gone up a portion of the way a vehement thunderstorm came up from the bay of Naples, with abundance of hail and snow, and a wind so fiercely cold that we were glad to crouch under and rest upon the hot 'colmo' of scoriaceous blocks confusedly heaped over the fluid lava. The hail and snow were followed by heavy rain; and we were only able to make observations and sketches of the lava-currents near us, and the cliffs of Somma above us; but these were what we came to see.

Quite recently (Aug. 8, 1868), stone-throwing has

been resumed from Vesuvius[1], and injuries have been sustained by two adventurous explorers. The appearances presented by the crater in quiet times will be mentioned in another place.

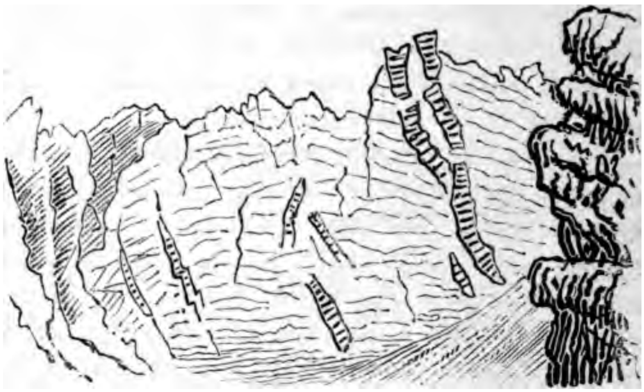


Diagram XXI. VOLCANIC DYKES IN MONTE SOMMA, 1868. (*Original.*)

Excepting that we did not and could not reach the high crater, our two ascents gave us all the information we required, to make intelligible and available the great abundance of observations already made public by many authors of eminence.

In the course of our instructive excursions we examined with care the whole coast-line from Pompeii to Portici, in reference to the history of the mountain and the shore, and the peculiarities of the lava-ridges, loose volcanic aggregates, and tufaceous deposits.

[1] Athenæum.

Accepting as true the traditions that Pompeii was anciently founded on a low promontory on the sea-shore, or on the shore of the Sarno then navigable, and that at its sea-gate iron rings were found in the wall for mooring vessels, we are prepared to admit, on quite other evidence, what geologists will readily believe, that the whole of this coast has been subject to vertical movement. It could hardly be otherwise in this volcanic region: but in fact there is reason to look to a much more general cause than local and violent disturbance for the elevation of the old sea bottom through all the Campagna of Naples, and yet this has happened after volcanic action had been set up, for all this plain has a basis of volcanic sediments accumulated in the pleistocene ages.

Cliffs of much interest begin at Torre dell' Annunziata, where the many-fingered lavas of A.D. 1631 come to the sea in considerable force and the coast-line makes a sudden bend. If the general level of the land were sunk 20 feet or so, the sea-line would run from Torre dell' Annunziata to Pompeii; and so it once probably did run.

No other lava-currents have reached the sea-shore in this quarter but those of A.D. 1631. They commonly occupy depressions in the ashes and cinders which fell in showers at some earlier time, and are sometimes covered by later accumulations of this nature. About three miles of the coast-line are occupied in this manner. Proceeding toward Torre del Greco to within a mile and a half of that town, we find fronting the sea, at the

base of a cliff, an ancient lava-stream, with uneven top, below masses of tufa and layers of ashes. On this lava, and set into and upon the tufa and ashes, are brick walls of Roman work, with characteristic mortar, and floors. There is also an excavation of old date in the tufa, lined with Roman plaster, and a cistern with similar lining and characteristic floor, a little thrown out of place.

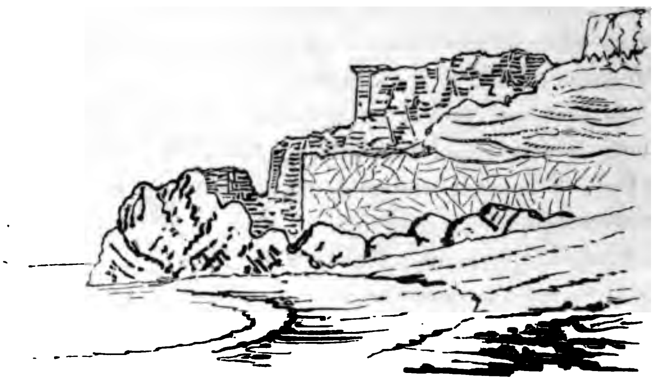


Diagram XXII. ROMAN WALLS AND FLOORS, built into and upon old lava, tufa, and ashes, above which appears another lava-current, 1868. (*Original.*)

In the same sections a higher lava-current is seen, probably of A.D. 1631, which rests upon the tufa and ash beds, which in places must be 60 feet thick. The place where this occurs is on the line of the railway, and is called Torre del Bassano. It appeared to be an important fact in the history of the mountain, and to fit with the statement already admitted as to Pompeii being

founded on prehistoric lava. In crevices of this ancient lava of Bassano we found plenty of oligistic iron.

By the side of the railway are excavations for the ferruginous ashes, known as 'tarras' or 'pozzolana,' which are so much valued in fine mortar and special cements, and are sent to London for this purpose. In one of these pits the deposit is covered by gray cellular lava with a scoriaceous top, the 'colmo del corrente,' and a rough, ochraceous, slaggy base. The cells are often large and elongated, and contain some undefined, probably leucitic crystallization.

Among the loose ashes which are stratified, and even finely laminated, are ejected masses called 'bombs,' which, on being broken, are found to contain analcime, gismondine, and comptonite, besides pyroxene and felspar. Under all is the ordinary coherent tufa.

More important, however, than these notes on the levels in tufa and the historic aspect of this part of the Vesuvian shore, were observations on two lines of ancient sea-level, which are plainly marked in the tufaceous accumulations under the lower ashes and scoria, on the line of the railway, at and near these fragments of old lava-currents. The appearances may be understood by Diagram XXIII. p. 136.

In the lower part of the ashy deposit an old plastered archway, partly walled up, is seen. The sea-level surface, *z*, is estimated to be 40 feet above the sea, that marked, *y*, to be 60 feet, and both were regarded as really produced by the same processes as those which are now daily shaping the shallow bed of this Mediterranean

shore into levels of the same kind. The soundings on this shore give depths so gradually increasing from the water-edge as to mark practically one continued plane,

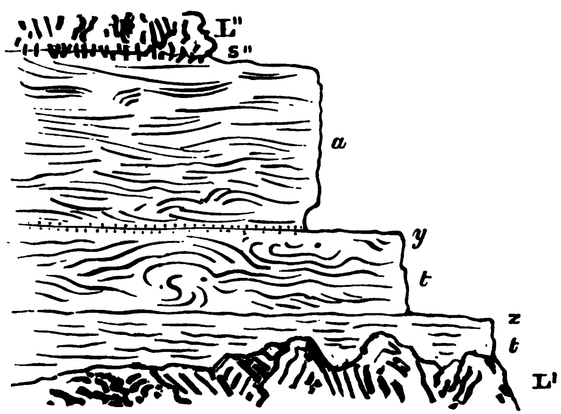


Diagram XXIII. BEDS OF VOLCANIC ASHES AND TUFA, enclosed between currents of Lava, at Torre del Bassano. (*Original.*) *L''*. Upper lava current. *s''*. Its scoriaceous base. *a*. Volcanic sands (ashes) and lapilli in undulated layers. *y*. An ancient level surface. *t*. Tufaceous beds, undulated. *z*. Another ancient level surface. *t*. Tufa below it. *L'* Prehistoric lava-current.

a circumstance attributable no doubt to the uniformity of the materials, and the total absence of streams and inlets. And this makes it the more remarkable to read in the notices of Herculaneum, that it was built on elevated ground between two rivers[m]. In the account

[m] See Murray's Handbook, p. 208. The authority is Sisenna, B.C. 91, fragment preserved by Nonius.

of the eruption of A.D. 79, Pliny the younger calls the port here Retina—now Resina.

Part of what is now called Torre del Greco stands upon lava of modern date; part of an older town is buried under lava; perhaps in a few years its history of casualties may be extended, but there will still be builders and occupiers of houses in this pleasant if dangerous site. At least three times has the flood of fire swept down to injure it: in A.D. 1631 the north-west side, and in A.D. 1737 the south-east side, were injured, but in A.D. 1794 the lava ran right down the streets, sweeping away houses and people, and reaching the sea in a broad high front. Nor then did its power cease, for it invaded the Mediterranean to the extent of about 126 yards, heated the waters for a distance of 100 yards more, and killed the fish. It came so quickly as to preclude the escape of some of the aged and infirm inhabitants, and prevent the removal of property, but the loss of life was not great. It is described as a swift current, yet really its average rate of movement was but one foot in a second, equal to that of a sluggish river. The statements made on some of these points by the guides usually err in excess.

The stone is more solid and more pyroxenic than most of the other lavas, and is consolidated in subprismatic forms of large diameter (Pl. IV. It contains leucite even largely crystallized. The slope of the lava as it was consolidated in the street of Torre del Greco is 5°.

Equally destructive, perhaps, was the earthquake of

A.D. 1861, which preceded the eruption of that year. Many cracks in the church and houses attest the effect of this calamity, which is proved to have been accompanied by a rise of the neighbouring coast to the extent of three feet and a-half.

Between Torre del Greco and Portici, similar appearances make the coast interesting: the lava cliffs being formed by the seaward ends of several branches of the great currents of A.D. 1631—the last of these supports the fort called Granatello.

Inland from the Granatello, under the town of Resina, under the lava of A.D. 1631 and the ashy showers which accompanied it, and under a far earlier and heavier load of consolidated lava-like mud, lies the ancient and renowned Herculaneum. An excellent account of this buried city, as well as of its sister in misfortune, Pompeii, will be found in Murray's Handbook for South Italy and Naples, a work which is remarkable for abundance of well-arranged information.

AFTER THE DESCENT OF LAVA TO THE ATRIO.

CHAPTER V.

CHARACTERISTIC PHÆNOMENA OF THE BEGINNING, PROGRESS, AND END OF ERUPTIONS.

'Excedit profecto omnia miracula ullum diem fuisse quo non cuncta conflagrarent.'—PLINY.

ON the ample basis of the narratives of eighteen centuries we may venture to sketch the type of an eruption of Vesuvius from the beginning to the end, treating the phænomena, not as themes for emotion, but as facts for reasoning out the probable causes. Bacon and Lyell have well said, 'Vere scire, est per causas scire.' According to the experience of this century, the mountain can rarely be found undisturbed by some remnant of a former or some indication of a coming eruption: the old fever slowly declines, the new disorder slowly advances; both change by steps, with pauses and renewals.

Before any actual evolution of vapour from the crateral summit, it happens sometimes that a cloudiness gathers there which seems due to a local peculiarity, not to the coldness of the season, on the mountain top. This may

easily happen, because of the moisture separated from the air in the shaded crateral hollow. It is no sign of eruption: something like it occurs in the rocky hollows among the Alps. A far more important fact is the sinking of water in the wells round Vesuvius—the total drying up of some, the increased descent of the bucket in all. The observation has been made too often and too carefully to allow of a serious doubt on the subject. What is the cause of it? and why is it an indication of coming disaster?

In England, with its variety of stratification, natural springs abound, and vary as to their discharge according to the previous season. 'As the days lengthen, the springs strengthen.' Wells sunk for water may be said to draw from the subterranean channels of the natural springs, the water rising in each, not according to the hydrostatic pressure of one general reservoir, which might make them all level, but according to the inclined plane of the several subterranean currents.

In Vesuvius, the deep absorbent soil without any alternating clays or interrupting clay-bordered fissures, natural springs and continual rills are very rare; torrents are occasional, and wells frequent and of the utmost necessity. Rain falling on the ashy cone sinks in some considerable proportion into the absorbent soil, and gathers into what may be called a subterranean bed, or water-bearing stratum, and moves on a descending plane toward one or a few natural outlets in the lower ground, or in the sea. This is not different in

principle from what happens in England. Wells sunk down to this current are fed with water from it, and the height of water in the wells is proportioned to the resistance on the natural course of the current at those points respectively. It is easy to show the truth of this explanation by models. The common notion of 'water finding its own level' does not meet the case of wells in a hilly country.

Deficiency of rain will be followed in England by weakening of the natural springs, and both in England and in Vesuvius by depression of the wells at some following date; any additional means of discharge, natural or artificial, applied to the lower outflow of the natural subterranean stream, will, by accelerating the discharge, depress the wells. This is known by experiments very frequent in England—Artesian wells in London for example—to be a real cause of a certain measurable effect.

Turning to Vesuvius, we find that the sinking of the wells cannot be explained by reference to the previous state of the weather. In 1812–13, Monticelli paid particular attention to this fact (chap. iv. p. 98), and his opinion appears to be supported by previous and subsequent occurrences. We are therefore obliged to adopt the inference that in some way or other, on the approach of an eruption, there is produced some additional means for the outflow of the subterranean water, by clearing or enlargement of the old outlets, or the production of new ones. Probably not by enlargement of the old outlets, because the effect in that case

might be expected to be permanent, and is transitory; probably by the opening of new ones, possibly in quite a different direction. We are thus brought to the tempting supposition of a diversion of part of the subterranean stream into channels of the mountain, which have been opened by an early effort of the volcanic agency. It is not necessary to suppose a direct downflow of water to the focus of fire, or a violent earth-shock; it is enough to admit of fissures in the interior masses of the mountain,—fissures occasioned by gradual pressure, not by sudden vibration.

Earthquakes are forerunners of eruptions; there are frequent earthquakes in Campania, without eruption; so it was in the days of Pliny, and then, as now, they occasioned no great alarm. If we follow out the idea arrived at in the preceding pages,—internal fissures arising from some kind of accumulating pressure,—the necessity of earthquakes following upon such a process in a volcanic region will be apparent. For thus the heated interior becomes opened to the admission of water; the generation of steam—the sudden shock—the far extended vibratory motion, are consequences of a slow change of dimensions, in presence of internal heat and admitted water.

The retirement of the sea and its sudden return, which seems to be a well-established fact, may perhaps be referred to the same cause, but the conditions under which it happens are not so well known as to make the problem one of easy interpretation. There is no reason to think the phænomenon is always met by the now popular

notion of the land rising: the occurrence seems to be quite local—only noticed on a certain small extent of shore—and there may be no earth-tremor of any kind observed, or rather it may be certain that none occurred.

If any one will have the courage to admit an opening made suddenly through the sea-bed, occasioned primarily by the production of fissures as already described, he may understand how this might, in a limited space of the seacoast, occasion both the withdrawal of the water and its return. The ascertained movement in either direction is for a few paces only. The opening may have been an old one concealed or impeded in the course of time, and merely re-opened, or cleared, or made to communicate with a new underground fissure. This seems the most likely reading of an obscure passage in the history of Vesuvius, on which it is to be hoped much more accurate evidence will be gathered by the able and experienced men of science in Naples, who have already done so much for the study of their 'own mountain.'

Fissures then, produced internally by some change of dimensions consequent on pressure, appear to be proximate causes of the forerunners of eruption. The probable origin of the pressure we may consider hereafter.

The eruption begins—let us suppose from the summit: vast volumes of clear transparent vapour, 'dry steam,' rush upwards, and are speedily cooled into cloud. Just as the clear steam from a locomotive engine first rushes up, then forms a long slowly-dissolving cloud, longer and more voluminous in a damp south-westerly air-current than in a dry north-easterly breeze; so on Vesuvius, the

enormous cloud rises rapidly to a vast height — shot upwards with the force of a cannonade—then yielding to the wind rolls away and dissolves in air, or collects into rain, according to the condition of the atmosphere. The rapid evaporation of water is known to produce electric tension in a very high degree, and violent discharge follows.

Even in the well-regulated atmosphere of a paper-mill, the thin revolving sheet of dried paper—dried by rapid evaporation—gives a stream of electric sparks ten inches or more in length; and it is no wonder if the electricity which accompanies the Vesuvian cloud is proportionally strong, and the 'ferilli' something dangerous. Whether these lightning-shafts shall strike the earth at all, and if so, where, depends on the conditions of the time and place. This kind of cloud-lightning may be often repeated and extended to very distant regions.

There can be no doubt, after considering the authentic drawings of Scrope and Hamilton for the years A.D. 1822 and A.D. 1767, and the many careful notices of other writers, that the column of vapour has risen over Vesuvius, in some instances, to two, three, or four times the height of the mountain, and that then it has diffused itself, under the influence of the wind, to considerable distances. Avoiding extreme cases, such as the eruption of A.D. 1779 referred to, when the current may have set toward Naples, and guiding ourselves by the drawing of Mr. Scrope, we may very safely admit as a fair estimate a cloud mass over Vesuvius, one mile in

diameter, and one mile high [a]. Not that it takes such globular form, usually. In such a cloud, supposing it to have been condensed to saturation at 40° Fahr., we may estimate the water at 20,000 cubic yards,—about the quantity contained in a pond of two acres, two yards deep. Such a cloud, continually renewed from below, and continually dissipated by re-evaporation above, would in the course of a few hours or days empty a few such fish-ponds: how many it is not easy to calculate on any satisfactory hypothesis of the conditions. It is enough to see that a large quantity of water rises in vapour during an eruption, and that such uncommon pluvial descents may follow, as we know to have happened. From such a cloud rain might fall to cover a square mile one quarter of an inch deep.

The evolution of the steam is by fits and starts, or even almost by rhythmical puffs and bursts, at intervals of a few seconds. When several mouths are in action together, the effect appears, at a distance, to be continuous. There seems no reason to doubt that the evolution takes place very frequently from the surface or the upper part of a mass of lava, within the crater; sometimes, to a less extent, from the current after its issue.

Contemporaneously, or by alternation at irregular intervals, a different kind of cloud rises even to the same height, formed of jets of ashes, as the term is, or rather

[a] The Italian narrators of Vesuvian eruptions employ such terms as globo, botta, &c, for the accumulated outburst of vapour and ashes; probably mindful of

'Quis globus, O cives! caligine volvitur atrâ?'

of volcanic grains and dust. Sometimes white watery vapour has risen from one mouth, and black ashes from another. Much of this is carried up by the rushing steam, not projected by independent force. Thus it arrives even at the upper part of the vapoury mass, and as that is carried on by the wind, especially if damp, for miles, so this afterwards travels with the current to much greater distances, and falls slowly on foreign lands, and seas, and cities. Only fine dust, we are told, travels so far. Such small particles having a very slow rate of falling, may be readily believed to reach much farther than Africa, Rome, Athens, or Constantinople: just as very fine sedimentary earthy matter has been shown by Mr. Babbage to require years or centuries for subsidence in the waters of the sea.

This volcanic dust is disintegrated lava; the dispersed components of the once fluid mass. Either by actual bursts of steam in the midst of the fluid rock, or by throwing upwards parts of the breaking and crushed solidified crust, dust, lapilli, and bombs are tossed into the air, evidently as much as 300, 1,000, 1,600, and 2,000 feet above the crater. Then follows a rain of stony masses, within and beyond the crater; within when the shots are directly upward, beyond when they deviate much from the vertical. The large masses having acquired velocity in falling, which they do not wholly lose on reaching the inclined surface of the ground,

> 'Roll, leap, and thunder down, impetuous to the plain.'

Some such of large size lie in the Atrio del Cavallo, and

will be visible for a few years, until covered by fresh ejections.

Lava pressed up from below, ascends to or toward the summit, in a truly liquid state; but of such a consistence as fused siliceous compounds usually have, and of such a degree of fluidity as the slaggy products of an iron furnace or copper furnace. Some lava has been noticed as of unusual fluidity; such ran down the valleys beyond Massa di Somma, and toward San Giorgio. Some lava quickly covers itself with a heapy ridge of loose scoriaceous blocks; some runs clear for great distances. Cooled by the air and the earth its course is necessarily limited to a few miles, and in fact no known Vesuvian current has run more than six miles. There is no reason to think that longer currents flowed in the time of the activity of Somma.

All the lava flows out under some pressure; when this pressure is too great for the containing walls of the cone, and an opening is made by some lateral fissure, the lava springs out with more freedom, and is likely to flow farther down the slopes, than when it starts from the crater. The main eruptions of A.D. 1761 and A.D. 1794 were from fissures which opened far down the mountain, and one of these is the current which entered far into the sea.

The speed of the current is usually very small, though near the source its movement has been found quick enough to be compared to the tide stream of the Severn. In general the slowest river in a plain moves faster than a lava-stream on a considerable slope:

it is a swift current which, away from the source, goes through a mile in an hour. Usually the rate is very much less. As the currents roll out with pauses and interruptions, and suffer congelation, they collect into fantastic ridges and knolls, cross and intertwine, fresh lava diving under old heaps, and then deserting the caverns which it made. On the whole they follow the natural hollows, but with extreme irregularity of depth and outline.

It is a prevalent notion that the outflow of lava constitutes the essential feature, or purpose if we may so speak, of the eruption; that when this occurs, the danger is over. This may be supported by particular cases; but there are so many examples of the renewal and repetition of ashy eruptions and lava-streams, with earthquakes and thunderings, as to leave no secure conviction that the flow of lava necessarily or effectually quiets the internal fever, even if it relieves the momentary pressure.

From an early period the 'bellowing like an ox' has been noticed as a warning-note of the approach of eruption. Of course it indicates the fact of the interior being disturbed, and the further fact that the atmosphere is set in motion by the disturbance. It is not likely to be heard while lava fills the funnel of the volcano, but may readily occur before and after that happens. Perhaps in some cases it may require the supposition of the presence of air in large quantities deep in the crater, a supposition very probably right.

Mud eruptions are spoken of in reference to Vesuvius,

but only in the language of hypothesis. There is no proof of such an occurrence, but it has been suggested that the consolidated mud-beds which cover old Herculaneum may have descended from the volcanic openings. An easier supposition is the gathering of such masses from the ordinary volcanic dust by heavy rain. Torrents of liquid, heavily charged with the grains of pozzolana, must have been slow in movement and quick in consolidation, so as to render it very unlikely they could run to a distance of six miles. There is, however, no improbability in the occurrence of such eruptions from Vesuvius at particular epochs of its changes, after the crater has been filled with disintegrated matter, which may happen to be the case before or after an eruption of the ordinary kind.

As the eruption phænomena die away, with feebler and less frequent ejections of stones, pumice, and dust, with smaller wreaths of black and white clouds over the crater, and contracted streams of lava; as the surfaces become cooled by radiation and atmospheric influences, a new order of phænomena appears, which it would be of great consequence to have watched as carefully as have been the more striking effects of convulsion. Gases arise, metallic substances are deposited, salts of different kinds crystallize in the crevices, and hang in stalactical shapes from the caverns of the lava. This process begins, or rather its effects become visible, very quickly after the eruption is said to have ceased: in reality the extrication of these elements must have begun before they are or indeed can be observed. As

the lava grows cool, the substances carried up in vapour begin to be condensed on the surfaces, and even for months afterwards some of the deposits continue, or are succeeded by others.

Steam, as Dr. Daubeny observes, is emitted, sometimes for ages together, on the flanks of many extinct as well as active volcanos, the one continuous effect of volcanic heat.

Of the permanently elastic fluids, one, muriatic acid, seems to be generated during almost all the phases of volcanic action; it has been collected from recently erupted lava, as well as from currents of previous years, and mixed with vapours under various conditions.

Sulphur, combined with oxygen in sulphurous acid, and with hydrogen in sulphuretted hydrogen, plays a considerable part among the gaseous products, and is separated from them in the solid state.

Nitrogen, alone, seems to be a very frequent concomitant of the later stages of volcanic action, and to be seldom absent from thermal springs, even if no other indication of former volcanism be traceable.

Carbonic acid is most frequently met with among extinct volcanos, or in the stages approaching rest in those regarded as active. It is indeed absorbed from the atmosphere by rain and exposed surfaces of water, but its source in volcanic regions is most probably referable to calcination of limestone.

The substances next to be considered become condensed on the cool surfaces of the volcanic solids. First of these is the singular product, derivable from

some organic bodies, called petroleum. It occurs among long-cooled substances of volcanic origin, and may be believed to be derived from particular strata, under the influence of interior heat.

Sulphuric acid—supposed by Dumas to be derived from catalytic decomposition of sulphuretted hydrogen in presence of water and porous bodies—is chiefly found in combination with water among extinct volcanos In union with bases of lime, soda, &c, it will be noticed immediately.

The substances next to be noticed are 'sublimed' in a solid state, that is to say, in vapours whose elementary particles are solid and condensed by cooling. One of these, boracic acid, is not commonly observed as a Vesuvian product, but occurs in the active volcano of the Lipari Isles, and in Tuscany. It is probably evaporated in connection with steam.

Ammoniac chloride (sal ammoniac) is collected in fissures of lava, within a day or two, and again as much as three months after an eruption; tinted with iron it constitutes a bright orange-coloured ornament to the slaggy lava.

Sodic chloride (common salt) is found in some condition in almost all volcanic aggregates mixed with the constituents as well as in the fissures. It is not necessary to suppose it a product from aqueous solution, being volatilizable at a strong red heat.

Plumbic chloride (cotunnite) is a late addition to this catalogue; being found principally in fissures of the lava of A.D. 1855, even for years after the consolidation of the current.

Ferric chloride (muriate of iron) is found among the sublimations of Vesuvius, though not on occasion of every eruption; during the pauses of the eruption now in languid progress it has been collected not unfrequently.

Ferric oxide (specular iron ore), usually accepted as a direct product of sublimation, has been of late regarded as a derivative from ferric chloride, the chlorine being separated in the atmosphere; it is not known to be sublimable per se, but may perhaps be carried up with chlorine.

Sulphur is collected about Vesuvius, and much more abundantly elsewhere, but is seldom thought to be raised in vapour alone. Either from sulphuric acid, or from sulphuretted hydrogen, the crystals of sulphur, so frequent and beautiful in Sicily, as well as the less conspicuous examples from Vesuvius and the Solfatara, may be satisfactorily derived. It may be regarded as belonging to the expiring stages or intermittent lethargy of a volcano.

Sulphides of iron, copper, arsenic, zinc, selenium, and lead, are to be placed in the same category as sulphur; they are believed to be secondary formations, not primary sublimations; these all occur in one form or other as among the products of Vesuvius and Somma; but the sulphide of lead (galena) and sulphide of zinc (blende) are found among ejected substances in Somma, not in fissures of Vesuvius.

'The sulphates of lime, alumina, iron, magnesia, and soda, which so frequently incrust the surfaces of recently

ejected masses, or the fissures of volcanos in present action, are evidently produced by the affinity of sulphuric acid for those alkaline and earthy bases with which it may have come in contact[b].'

One product, if it may be so called, of Vesuvius has not been mentioned—flame. It may seem strange that any doubt should exist as to the reality of an event which figures in almost every popular description of a volcano. Is there really no flame in all that red glare which fills the sky, and is reflected on the sea, and enables a politician to read the news at a distance of twelve miles in a dark night? Perhaps not. In the majority of cases it can be clearly seen that the light emanates from incandescent, but not flaming bodies. It is the light of the glowing lava, and masses ejected in a state of white or red heat, which makes the great column of seeming flame rushing up from Vesuvius.

Yet flames have been observed in a few examples by persons too surely observant to leave much room for doubt. Davy is one great authority, and Professor Pilla of Pisa another. In June, 1833, this intrepid philosopher ascended the mountain toward the close of an eruption, stood upon the small discharging cone, and witnessed an explosion. This is what he heard and saw:—

'A loud subterranean noise and a violent shock announced the explosion: immediately after, and almost at the same time, the mouth opened, and made a discharge with a noise resembling that of a discharge of

[b] Daubeny, Volcanos, p. 615, 2nd edit.

cannon. A column of black and fuliginous smoke issued with great violence, and there was thrown up, with the rapidity of lightning, an enormous torrent of inflamed gaseous substances and burning stones, which fell back like hail, for the most part into the gulf, but partly outside of it. Though overpowered by the grandeur of the spectacle, I did not fail to observe the column of flames which accompanied the explosion. It rose to the height of four or five yards, and then disappeared among the volumes of smoke, so that a person whose eye was on a level with the edge of the gulf could not have seen it. Hence it is that the existence of flame has been so confidently denied. The flame which I observed was of a very decided violet-red colour.'

Hydrogen was perceived on this occasion by the smell.

On another occasion, beautiful greenish flames, probably tinged by chloride of copper, were observed—muriatic acid was prevalent. On a third occasion, reddish-white flames, three yards in height, were seen—muriatic acid was abundant. The flames were believed to arise from hydrogen in combustion.

For observations on this curious subject, the spectroscope may be expected to be of great service.

CHAPTER VI.

PERIODS OF REST AND ACTIVITY.

'Nec quæ sulfureis ardet fornacibus Ætne
Ignea semper erit; neque enim fuit ignea semper.'
OVID, *Metam.* xv.

On considering with attention this long series of events connected with one volcanic centre,—the best and most authentic series of the kind,—we perceive alternations of periods of rest and activity. These periods are very unequal, and seem to be marked by no rhythm or common measure of time analogous to that which is observed in the spots on the sun, which are thought to have somewhat the character of volcanic disturbance, seen through a fluctuating envelope. Yet from the general uniformity of the effects,—earthquakes, explosions of steam, ejections of certain sorts of ashes, the efflux of certain kinds of lava,—it can hardly be doubted that there is a law of the effects depending, as in other geological phænomena, on time; a law such as to admit of the idea of a definite origin; of arrival at

a maximum, and of final reduction to zero. For as Ovid or Pythagoras, declares,—

> 'Nempe ubi terra cibos, alimentaque pinguia flammæ
> Non dabit, consumptis per longum viribus ævum,
> Naturæque suum nutrimen deerit edaci,
> Non feret illa famem; desertaque deseret ignes.'

Whatever theory we adopt as to the exciting cause of volcanic energy, this cause must bring its effects to an end in Vesuvius, after passing through the long stages of slow decay which are revealed to us in Avernus, the Alban and Euganean Hills, Auvergne, the Eifel, and the Drachenfels, in all which places some feeble phænomena remain to attest the former violence of nature. And in the course of this inevitable and long-enduring change of intensity, it is easy to conceive, or rather hard to avoid admitting, smaller cycles, of increase and decrease of effects, whose periods are comparatively short, and may be very unequal. The catalogue of Vesuvian eruptions is indeed very incomplete, not only as to the measures of eruption-force, but even as to the occurrence of eruptions, for with Dion, Procopius, and Hamilton, we may hold it as certain that very many have been omitted and forgotten.

If, as in the following table, we represent vertically the flow of time in centuries from some epoch not too remote, say B.C. 600, and mark each recorded eruption by an asterisk, the long rest before the great Plinian outburst, and the long pauses between that and the equally fearful eruption of A.D. 1631, will become conspicuous. Again, after the date just given the eruptions become frequent, and

	Ætna and Lipari.	Vesuvius.	Phlegræan Tract.	
A.D.				A.D.
19th cent.	* * * * * * * * * *	* *		19th cent.
18th cent.	* * * * * * * * * * * * * * *	* *		18th cent.
17th cent.	* * * * * * * * * * * * * *	* * * *		17th cent.
16th cent.	* * *	*	*	16th cent.
15th cent.	* * * *			15th cent.
14th cent.	* *	*	*	14th cent.
13th cent.	* *			13th cent.
12th cent.	*	*	*	12th cent.
11th cent.		* *		11th cent.
10th cent.		*		10th cent.
9th cent.	*			9th cent.
8th cent.				8th cent.
7th cent.		*		7th cent.
6th cent.		*		6th cent.
5th cent.		*		5th cent.
4th cent.				4th cent.
3rd cent.	*	*		3rd cent.
2nd cent.				2nd cent.
1st cent.	*	*		1st cent.
B.C.				B.C.
1st cent.	* * *		*	1st cent.
2nd cent.	* * * * *			2nd cent.
3rd cent.			*	3rd cent.
4th cent.	*			4th cent.
5th cent.	* *		*	5th cent.
6th cent.				6th cent.

overcrowd the limited spaces allowed for representation. During the last 238 years these phænomena have been far more numerous than in all the previous centuries known to history, and though, no doubt, some were neglected during the troubled ages which followed the extinction of the Imperial rule in Italy, while in modern times few have wanted observers competent to record them, still the general result appears trustworthy, as showing greater activity in the disturbing causes or reduced obstacles to the outflow of lava and outpours of stones and dust.

The alternations of rest and activity in Vesuvius have been often enough observed of late years, to justify an opinion that after a great display of excitement by which the crater has been cleared out, degradation of the sides happens, and materials are raised in small quantities from below, so that in the course of years, many or few, the crater becomes filled, or tends to be so, and thus the channels to the surface are choked, and can only be restored by violent effort from within. Taking this as correct in the main, the question next occurs whether the Vesuvian volcano is fed from physical agencies limited to it alone, or subject to a more general condition affecting a large tract of country near it or remote from it. For if it be the channel of a single detached fire-force operating beneath and near it alone, there should be a series of eruptions and pauses either at approximately equal intervals of time, or at intervals growing longer regularly, or shorter regularly. But if not so, if the eruptions are merely local effects of

a cause whose area is far extended round Vesuvius, that being only one of the channels to the surface, its efforts may appear to be very irregular, and not to be reduced to any common measures of time. Now on this point the preceding table will help us to a right judgment. For by arranging in it a column of remarkable eruptions which occurred in some of the nearest volcanos, as Monte Nuovo, Solfatara, and Ischia, as well as of others which happened in Ætna, the Lipari Isles, and Santorino, we see at once a general reciprocity of eruptions, and some evidence of a common underground connection.

Thus before the first great eruption of Vesuvius, Ætna and the Lipari Isles had been for ages in activity; ten eruptions of the Sicilian volcano being recorded between B.C. 480 and A.D. 40; and great eruptions had happened in Ischia in the fifth, third, and first centuries B.C. After the exhaustive eruption of Vesuvius in A.D. 79, above 1,000 years passed with but few remarkable exhibitions of energy either in Vesuvius or the region to the west of it, or in Ætna. It seemed as if all the Italian system of subterranean fire was subdued in energy. But then in A.D. 1108 the Solfatara erupted, in A.D. 1302 Ischia, in A.D. 1538 Monte Nuovo; while three eruptions came from Vesuvius before the grand convulsion in A.D. 1631, and sixteen from Ætna. Ever since A.D. 1631 Vesuvius and Ætna have been in almost continual rivalry of activity; upwards of thirty eruptions are recorded in Ætna by Dr. Daubeny up to A.D. 1842, and forty-three in Vesuvius. These

numbers are greater than those usually adopted, though even in this catalogue not every special separate flow is recorded; and thus we have the assurance that while in a general sense there is a correspondence of phase between the two systems, there is rarely any approach to special agreement of date—the nearest being in A.D. 1694 and A.D. 1811, when they occurred within a month of each other; on eight other occasions there was less than half-a-year between them.

Again, recurring to the same table, we observe in the Ætnean eruptions a certain frequency in the five centuries B.C., so that within that period eleven eruptions are on record, while Vesuvius was silently at rest. After this more than twice as long a period passes, and only three eruptions are reported of Ætna, and eight of Vesuvius. Then follows a period of continually growing activity in Ætna for 400 years, while Vesuvius shows less frequent eruptions. But since that date both exhibit their energies very frequently, Ætna setting the example in A.D. 1603, Vesuvius following in A.D. 1631. It appears from this that the Sicilian volcano has passed from a state of energy through a long period of depression, to a second and more remarkable maximum, the period being about 2,000 years; while Vesuvius must be supposed to have had a depression of energy for at least 3,000 years: for the pre-historic eruptions can hardly be supposed to have been frequent at a later æra than B.C. 1000.

In the same way we remark in the column of Phlegræan eruptions, a probable maximum about two or

three centuries B.C., then twelve centuries of depression followed by eruptions of which the mean epoch was about A.D. 1303,—giving a period of about 1,600 years. If we might venture to trust such analogies, it would appear that the activity of Ischia and the Phlegræan tracts is exhausted in four or five centuries; and that a longer period of energy—say seven or eight centuries—may be assigned to Ætna; the Vesuvian period being quite unknown.

Once more, to consider these curious facts more generally, let us make another classification of the dates, and add the valuable information which may be found in a third volcanic tract whose history is very important, even in relation to the Italian volcanos,—far away as it is situated—Iceland.

In the table on p. 162 the number of eruptions is counted in columns, those of Vesuvius combined with the Phlegræan eruptions; to Ætna in the same way are added the Lipari explosions; and a third column gives the numbers for the Icelandic volcanos. The arrangement is by centuries—the nineteenth being included. The numbers are taken from Dr. Daubeny's treatise on Volcanos, with some few additions. The comparative numbers are interesting, and tend to a remarkable result.

First, it will be seen that as a whole the Vesuvian tract is now in a condition of *greater frequency* of eruptions than in any previous period. Next, it would seem that Ætna had reached the maximum of activity, or was even passing beyond it about the end of the eighteenth

century. Very much the same inference is clearly derivable from the Icelandic catalogue, which is by far the fullest in the eighteenth century, being however not deficient through the five previous centuries. The maximum appears to have been attained in the eighteenth century, when several mountains were in eruption contemporaneously.

Centuries.	Vesuvius, &c.	Ætna, &c.	Iceland.	Sum.
19th	24	10	6	40 } Max.
18th	23	15	31	69 } A.D.
17th	4	14	6	24
16th	2	3	7	12
15th	1	4	4	9
14th	2	2	12	16
13th	—	2	11	13
12th	2	1	5	8
11th	2	—	3	5
10th	1	—	1	2
9th	—	1	1	2
8th	—	—	No information	—
7th	1	—		1
6th	1	—		1
5th	1	—		1
4th		—		—
3rd	1	1		2
2nd		—		—
1st	1	1		2
0				
B.C. 1st	1	3		4 } Max.
2nd	—	5		5 } B.C.
3rd	1	—		1
4th	—	1		1
5th	—	2		2

On the whole, there appears good reason to adopt the conclusion which the fourth column brings out, that not less than 2,000 years is the average interval between two epochs of maximum eruption-frequency, in the

combined systems of active European volcanos, and that these apparently separate systems may have a common dependence on some general recurring condition, more extensive than the whole triangular area within which they are placed. What may that condition be?

These investigations refer to the *number* of eruptions, without reference to their violence or *magnitude*, or the mass of matter ejected from below. If we attempt to bring this into the computation we shall find the data insufficient for any exact result. In respect of Vesuvius, the eruptions which stand out very prominently, as examples of great intensity, are those of the years A.D. 79, 1631, and 1822. Allowing these to have been remarkable for intensity, and for great abundance of ejected dust, stones, and lava, we may still have a doubt whether long-continued ejections such as those of A.D. 1766 and 1767, and such prolific vents as those of A.D. 1794 and 1858, may not have consumed as much of the fiery energy of the mountain as the shorter and more violent efforts of the three first-named eruptions. Even if we were to allow to the eruption of A.D. 79 ten times the effect of an ordinary or average eruption, this would not materially affect the result, which would always give a maximum very decidedly to the modern period. Still less easy is it to point out accurately the relative importance of the Ætnean and Icelandic eruptions, though for the former A.D. 1669, and for the latter A.D. 1783, are dates that rise at once to memory. In the present state of our knowledge the conclusion already suggested from a study of the number of

eruptions in a given period may be adopted with some confidence in its truth.

In the Report on Earthquakes presented by Mr. Mallet to the British Association a table is given of the occurrence of these phænomena in Europe and the adjacent parts of Africa and Asia, arranged in centuries, from A.D. 306 to 1843. In the same work is another table, with a supplement, of earthquakes in the Italian district.

If we place in parallel columns the number of earthquakes and the number of volcanic eruptions, the degree of accordance will be seen at a glance. The eruptions are counted to the same epoch (A.D. 1843).

Centuries.	European Earthquakes.	European Eruptions.	Italian Earthquakes.	Italian Eruptions.
19th	925	26	478	23
18th	660	69	458	38
17th	180	24	130	18
16th	110	12	37	5
15th	.. 41 ..	.. 9 ..	.. 65 ..	.. 5
14th	58	16	71	4
13th	55	13	41	2
12th	68	8	40	3
11th	51	5	12	2
10th	.. 17 ..	.. 2 ..	.. 11 ..	.. 1
9th	36	2	6	1
8th	11	0	3	0
7th	10	1	1	1
6th	31	1	3	1
5th	.. 25 ..	.. 1 ..	.. 5 ..	.. 1
4th	21	0	6	0
Sums ..	2299	189	1367	105
Ratios..	1000	82	1000	77

It may be remarked, that in the twelfth, thirteenth, and fourteenth centuries there is an increase in Euro-

pean earthquakes, and in the thirteenth and fourteenth a corresponding increase of European eruptions; while Italian earthquakes are augmented in the fourteenth and fifteenth, and Italian eruptions in the fifteenth and sixteenth. All the phænomena grow rapidly in number in the last three or four centuries. It is curious to remark the almost equality of ratio of Italian earthquakes to Italian eruptions, and European earthquakes to European eruptions. Taken together the ratio is 80 eruptions to 1,000 earthquakes.

In the modern enquiries regarding earthquakes, attention has been paid to the seasons of the year; and it has been found by M. Perrey of Dijon and Mr. Mallet that there are really differences in this respect, so that some portions of the year suffer more frequently by earthquakes than others.

The records of volcanic eruption are more complete for Ætna and Vesuvius than for any other known mountains, and though not numerous enough for a just computation of the dependence of eruptions on the seasons of the year, they offer some interesting points for reflection.

In Dr. Daubeny's treatise on Volcanos we find collected the monthly dates of the principal eruptions of Ætna and Vesuvius, between A.D. 1631 and 1834 inclusive. In some cases eruptions were regarded as continuing through a year or part of a year. If we assign to each month the number of eruptions due to it according to Dr. Daubeny's list, the result will be as in the following table, which shows some remarkable

facts. The mark + indicates the month of greatest frequency.

Ætna.		Vesuvius.		Sum.
January	0	January	0	0
February	3	February	4	7
March +	7	March	3	10
April	2	April	2	4
May	3	May	5	8
June	4	June	4	8
July	2	July	8	10
August	1	August	8	9
September	2	September	4	6
October	4	October	9	13
November	3	November	5	8
December	2	December +	11	13
Sum	33	.. .. ..	63	96
First half of year	19	.. .. ..	18	37
Second half	14	.. .. ..	45	59
Six consecutive months of greatest frequency.	February, March, April, May, June, July	July, August, September, October, November, December		

The first half of the year exhibits no more than 18 eruptions of Vesuvius, but the latter half 45: on the contrary, Ætna gives 19 eruptions in the first half, and only 14 in the latter half. The monthly average of eruptions in Vesuvius (in 204 years) is $\frac{63}{12} = 5{\cdot}25$; in the first half of the year $\frac{18}{6} = 3{\cdot}00$, in the second $\frac{45}{6} = 7{\cdot}50$: while in Ætna the monthly average being $\frac{33}{12} = 2{\cdot}75$, the first half of the year has $\frac{19}{6} = 3{\cdot}166$, and the second $\frac{14}{6} = 2{\cdot}33$.

Another way of viewing it is this: the six months ending with July are the most full of eruptions

from Ætna, while the six months beginning with July are those in which most eruptions are quoted from Vesuvius. It should be noted that when an eruption is said to last for the interval between two months, say May to August as in A.D. 1707, all the intervening months are counted.

It is singular that within this period of 204 years, no eruption is signalized by Dr. Daubeny in the first month of the year; though the records which have been collected in an earlier chapter show that volcanic action has been apparent, if not conspicuous, in January, which has not been entirely protected by the Saint who bears the name.

The mountain has been wholly or partially covered by snow on the occasions of three eruptions.

By the discussion of earthquake phænomena already alluded to, Mr. Mallet obtained the following numbers, expressing total monthly occurrences of seismic phænomena in the Northern Hemisphere.

		+ Above Average.	− Below Average.
January	627	137	—
February	539	49	—
March	503	13	—
April	489	—	1
May	438	—	52
June	428	—	62
July	415	—	75
August	488	—	2
September	463	—	27
October	516	26	—
November	473	—	17
December	500	10	—
	5879		

The monthly average is 490. In the columns marked + and — we have expressed the actual monthly deviations from this average: from which it is evident that in the six months from April to September inclusive, the earthquakes are much less numerous than in the other six months, from October to March inclusive: in other words, the maximum is in winter, the minimum in summer.

If we make a corresponding table of volcanic events distributed in months, including Ætna and Vesuvius, we shall have—

		+ Above Average.	— Below Average.
January........	0	—	8
February	7	—	1
March	10	2	—
April	4	—	4
May	8	—	—
June	8	—	—
July	10	2	—
August	9	1	—
September......	6	—	2
October........	13	5	—
November......	8	0	0
December	13	5	—

The total is 96, monthly average 8. The columns + and — show the actual monthly excess or defect. From which it is evident that in the first six months the balance is 11 against, and in the last six, 11 in favour: a very marked difference, corresponding with nothing so much as the relative quantities of rain in the two halves of the year.

But as in fact earthquakes often of some considerable duration usually precede eruptions, we may find in this fact a reason for the difference of the seasons of their maximum frequency, the mean date of eruptions having a primary dependence on that of earthquakes. The maximum of earthquakes is in the middle of the winter season, when the earth is nearest to the sun.

Sir W. Hamilton mentions an opinion held by local observers of Vesuvius, that its efforts appeared subject to lulls at midday and midnight, and that he was disposed to regard the opinion with favour. It is only with reference to the moderate and long-continued efflux of vapour and ejections of ashes that such a view can have been founded on observation. It is obvious that the voluminous appearance of aqueous vapour would be much influenced by the state of the atmosphere, as to heat, dryness, and direction of wind; and that this complexity of accessory circumstances renders long and careful diaries necessary before accepting as probable bimeridian influences. The possible influence of the moon on eruptions of this character is a question of equal difficulty, for which till lately no adequate data have been collected.

It is a common belief among persons who do not require strict proof of propositions which they accept, that 'the weather' has influence on such phænomena as earthquakes and volcanos; the same minds may readily admit the influence of the moon on the weather; and thus we arrive easily at the opinion that Vesuvius is governed in its activity by the phases of the moon. On

the other hand, men trained in exact reasoning are apt to deride such notions as quite unworthy of enquiry. Neither of these conditions of mind is right, when the problem is one like that of volcanos, for which a just solution cannot be had without taking into careful estimation all the known forces which may be influential on the epoch, duration, and intensity of the effect.

Sir W. Hamilton begins his observations on Vesuvius by remarking that 'the smoke from the mountain was much more considerable in bad weather than when it was fair;' and he 'often heard (even at Naples, six [eight] miles from Vesuvius) in bad weather the inward explosions of the mountain.' Reflecting upon the facts observed in respect of the smoke from the summit, Sir W. Hamilton professed the belief that 'the weight of the atmosphere in bad weather, preventing the dissipation of the smoke and collecting it over the crater, gives it the appearance of being more considerable; whereas in fine weather the smoke is dispersed soon after its emission.' In this attempted explanation we may perceive the imperfect state of the science of meteorology as known in A.D. 1766. If for 'weight of the atmosphere' we read 'dampness of the air,' the view of this truly able observer will appear to be a reasonable one. He also reports as 'the common-received opinion at Naples, that when Vesuvius grumbles, bad weather is at hand.' From his own observations he thinks this opinion well founded, and adds,—'The sea of the Bay of Naples, being particularly agitated and swelling some hours before the

arrival of a storm, may very probably force itself into crevices, leading to the bowels of the volcano, and by causing a new fermentation, produce those explosions and grumblings [a].'

Quite recently, Professor Palmieri, who is engaged on the study of the physical facts which precede, accompany, and follow volcanic eruptions, has affirmed that the often-observed discontinuity or varying intensity of the lava-currents during the eruption of A.D. 1867–68, had two maxima and two minima, in each day; and that the ejections of ashes and stones followed the same law. And further, he found reason to admit a certain retardation day by day of the hours of maxima and minima. The nearest guess at the cause of this points to the moon, whose phases have already been supposed to have some influence on the epochs of earthquakes. And Palmieri has found in fact that through the whole period in which the eruption was observed up to April, 1868, the epochs of greatest force, both as to activity of ejection from the cone and abundance of lava, were at the syzigies, and the epochs of least activity at the quadratures of the moon: in this respect corresponding with the tides.

[a] Sir W. Hamilton, Letter I. from Naples, June 10, 1766.

CHAPTER VII.

FORM AND STRUCTURE OF VESUVIUS.

'Parendo appunto che la natura ci abbia voluto lasciare scritto in questa terra tutti gli incendii memorabili racontati delli autori.'

BRACCINI.

VESUVIUS, regarded in any direction, at any distance —over the Campagna, or over the sea—is an object of singular beauty and grandeur. Rising alone from a broad base and from the level of the sea, its outlines sweep upwards in an easy curve, growing continually bolder toward the summit, and there, in ordinary periods of tranquillity, passing over an uneven but variable 'dome' or 'cone' 4,000 feet high, to slopes on the opposite face not tamely identical, but harmoniously diverse. If the view be from Naples eastward, as in Plates X and XI, the northern outline, in happy contrast with the opposite one, is broken by a deep hollow, which is itself overlooked by a sharp angular crest 3,760 feet above the sea. Thus the mountain appears double: the northern crest is now called the 'Monte Somma,' the hollow is the 'Atrio del Cavallo,'

and the dome-shaped summit, now the highest part of all the area, is the modern 'Monte Vesuvio.'

But if the observer take his stand to the south-west, in the direction of Sorrento or Capri, the appearance is very different. Vesuvius is in front, and its long continuous slope comes down to Pompeii on the south, and to the sea at Torre del Greco and Resina on the west; while on the north it is encircled by the rugged crests of Somma. (Diagram XIII.)

The mountain is, in fact, double: and the modern 'cone,' as it is called, of Vesuvius, has been accumulated partly upon and partly within the old crater of Somma; accumulated in such a manner as to have nearly obliterated the south-western half of the old crater, but to have left untouched the north-eastern half, which remains, high and stern in its natural ruggedness, except where atmospheric vicissitudes have produced detrital slopes.

The southern and western outline of the large old crater of Somma is not so entirely covered by the Vesuvian lavas and ashes but that it can be traced, and has been marked on the maps of the Neapolitan territory under the name of the Pedimentina. In our Plates II and XI it may also be distinguished, as a continuation from the high crest of Somma, but at a much lower level.

If for convenience we employ the names of Somma and Vesuvius as distinguishing two parts of the great volcanic mountain, their history, as known to us, is strikingly different. Somma, the broken crest of the

greater and earlier volcanic crater, has been unmoved in place, unchanged in form and height, through eighteen centuries; a grand and awful fragment left after the poetic 'struggle of earth and sky,' and full of peculiar records of the combat.

Vesuvius, born of Somma, and seated within the encircling grasp of its parent, is a variable heap thrown up from time to time, and again, not seldom, by a greater effort of the same force, tossed away into the air, and scattered in clouds of dust over far away countries. Thus it has happened often, in the course of these variations of energy, that Vesuvius has risen to a conical height exceeding that of Somma by 500 or 600 feet, and again, the top has been truncated to a level as low as Somma, or even as much below that mountain as we now behold it above. 'Five times,' says Mr. Scrope, 'within the last hundred years, the cone of Vesuvius has been gutted by explosive eruptions of a paroxysmal character, viz. in A.D. 1794, 1822, 1831, 1839, and 1850, and its central craters formed in this manner as often gradually refilled with matter, to be again in due time blown into the air [a].' Thus two classes of forms arise in the study of Vesuvius: one may be called the old or Somma form, left after violent and exhaustive efforts of the volcano; the other the new form, in which Vesuvius takes a place unrecorded in ancient history, and never, perhaps, distinctly recorded at all for the English reader till the

[a] Treatise on Volcanos, p. 189, 2nd ed. 1862.

great observer, Sir W. Hamilton, turned his intelligent eyes on the Phlegræan Fields and the dominant mountain, in A.D. 1754. Our excellent Italian guides conduct us safely backward in time to the well-observed eruptions of the earlier part of the eighteenth century; and for all these years the expressive, if quaint, engravings of Sorrentino and Della Torre supply instructive data. The large views of Vesuvius under eruption presented by these authors are of great interest and certain authority.

For epochs previous to that time we have only word-paintings, and those not of a kind to be trusted beyond the dimmest outline, strengthened by the results of reasoning on the basis of modern observation. It will be useful, however, to present a few of these varying forms as types of often-repeated effects. Much more frequently repeated, indeed, than authors have generally supposed, if we may confide in the statements of Dion Cassius, Procopius, and Hamilton, which all point to many unrecorded efforts of the subterranean energy of Vesuvius [b], within the historic period.

It is usually, but not correctly, said that the eruption-cone of Vesuvius stands centrally with regard to the ring crater of old Somma, as traced round the western slope in the Pedimentina. It would be more correct to say the eruption axis of Vesuvius corresponds with the vertical axis of Somma: the eruption crater of Vesuvius appears in fact quite excentric with regard

[b] See pp. 40-45.

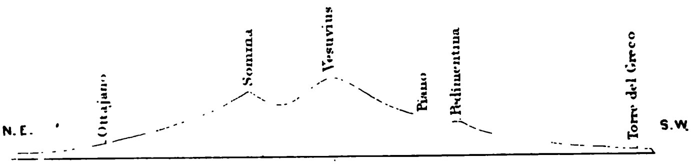
to the crater ring of Somma, because this latter is of such unequal height above the sea, that in the Pedimentina it is 2,000 feet below the highest crest of Somma: and for this reason, while there is only about one mile in a straight line from the centre of Vesuvius to the summit of Somma on the line to Ottajano, there is more than a mile and a-half from the same point to the Pedimentina, over Torre del Greco.

The several drawings on Plate II may now be consulted, all being drawn to the same scale, vertically and horizontally, the whole breadth or diameter of the mountain being taken at 40,000 feet, and the view always from Naples.

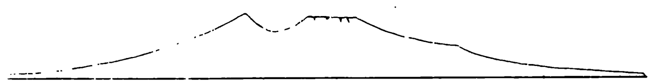
The lowest drawing represents the outline as it probably appeared in the days of Spartacus, and for nearly a century and a-half afterwards. The form assumed in accordance with the events of history and the description of Strabo, represents a truncated cone, somewhat higher than the present crest of Somma, because it is probable that that crest, as we see it, was one of the effects of the great eruption of A.D. 79. The top has a diameter of a mile and three-quarters, which would allow within it a crateral plain one mile across—space enough for the encampment of the small army of Spartacus at the beginning of the Servile War—'prima velut arena viris.' It was 'nearly a level surface,' deeply sunk below the encircling walls, uneven, no doubt, and probably marked by small hollows, if not ruined and degraded cones of final eruption.

In a condition still earlier than this, earlier than all

Pl. II

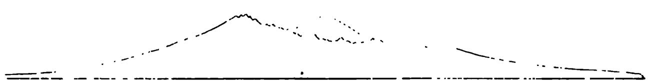


1868

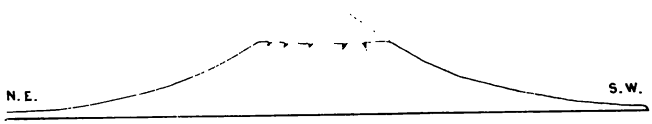


1822

1767



A D. 79 to 1631



B.C. 63

J.P. del^t J.W.L. sc.

record or tradition, the mountain was most probably higher (7,000 feet) and terminated by a smaller crateral opening, as represented by the dotted line: the space between it and the outline below is the section of the mass which the mountain may be supposed to have lost by some great and very ancient explosion.

The second diagram is meant to represent the state of the mountain after the terrific convulsion of A.D. 79, in the days of Titus and Pliny. All the upper part of the mountain is supposed to be lowered; in the south-western part most so, and in this direction the crateral edge, already so large, to be extended to the step or ledge still recognizable, called the Pedimentina, and still traceable, spite of so many subsequent eruptions, in the general circuit of Somma. No mention occurs in any writer of any cone, in the midst of the rough and ample mountain top, such as Vesuvius now is, nor of anything to represent it; yet it is most probable there was some cone, or even there might be several small cones in the area: for it is hardly conceivable that the vast eruption of loose lapilli, scoriæ, and ashes could end without some conical heap or heaps within the great disturbed area. One such cone is represented by a dotted outline.

Before the great eruption of A.D. 1631, which in several points emulated that of A.D. 79, the broad crateral space was visited by Braccini (see p. 45), and was found to be most rude and precipitous, with vast inner depths, and three pools of water, the relics probably of as many old internal degraded craters. The

mountain must then have resumed nearly the figure which it had after A.D. 79. It appears that some cone existed, from which the eruption happened; Dr. Daubeny admits a cone, 350 feet high above the crateral plain, with a deep circular lake on the summit [c].

The outline given for A.D. 1767 represents a particular phase in the eruption, when Sir W. Hamilton observed the formation of a small cone within the larger ordinary cone, as it may now be called, of Vesuvius. There were indeed three cones, one within the other, observed by him on this remarkable occasion. But in general the form of Vesuvius as seen in relation to Somma from Pausilippo, the residence of Hamilton, in A.D. 1767, and A.D. 1779, was hardly different from the shape it wears at this day; and we are the more struck by this fact, as of importance in estimating volcanic effects, by comparing it with the well-known descriptions of the mountain after the great eruption of A.D. 1822. The general effect of this eruption was to leave a vast precipitous crateral hollow, from one-half to three-fourths of a mile in diameter, in place of the old cone, and to lower the height from 4,200 to 3,400 feet, while in the interior was a deep cavity, a real inferno, at first 2,000 feet deep, according to Forbes, and afterwards 938 feet according to Babbage (see p. 102). Mr. Scrope published an original drawing of this tremendous crater in the Quarterly Journal of Science for 1823, vol. xv. Of this a reduced sketch is given, Plate IV.

[c] Volcanos, p. 226, 2nd ed.

Above the others, the outline as it appears at present is given for comparison; the escarpment of Somma being taken as on a line of its steepest slope. As it appears from Naples with the long continuous crest to the south-east, the outline is different.

The changes of form which have now been traced in a few types have been accompanied by great apparent differences of height, but on closer examination these are found to depend mainly on the accumulation or dispersion of loose or liquid materials around one central axis of eruption. Not absolutely or wholly so, for there have been several eruptions bursting from the sides of the great chimney, as well as from its summit, and others very far down the slope toward the west and south-west, even below the range of the Pedimentina. But these have had no great effect on the outline or the height.

There is no reason for admitting that in the whole course of history Vesuvius has ever been higher than it is at present: perhaps it has never been quite so high. But in pre-historic times, there is good ground for believing that the conical sides of Somma were at one time prolonged upwards to meet, or nearly meet, in a point, 3,000 feet or so higher than the present summit: and it is not an extravagant fancy to conjecture that in the course of ages on ages, if the action of Vesuvius should continue so long in the direction it now takes, the whole mountain may again be formed into one conical mass, the Atrio filled, the Piano raised, and the outline restored to what it probably

was before there were any of the many races of men who have

> 'Lived within the range
> Of the volcanos, and their mountain torch.'

Drawings of Vesuvius are seldom free from the usual error of exaggeration, either in regard to apparent elevation or the steepness of the slopes. In that splendid work of Sir W. Hamilton, entitled 'The Phlegræan Fields,' Signor Fabri has executed his pictures with more than common fidelity. The steepest part of the great eruptive mound taken on a sufficient length of slope commonly measures about the usual angle of rest in loose materials; 28° to 30° is rarely exceeded on the outward slope of Somma. From these angles, which are toward the highest parts in each case, the inclinations diminish to 18°, 10°, 5°, and 3°: and so gradual is the change that only a freely sweeping line can justly express the form. Only on the southern front of Vesuvius, the not quite obliterated edge of the original crater, represented by what is called the 'Pedimentina,' must be marked with more or less distinctness, according to the hour of day and the accidents of light and shade.

Martin's fine drawing for Gell's 'Pompeiana' must be imagined to represent the very greatest combined effect of cloud-ejection from the summit, and lava-current down the southern slope, ferilli darting behind the dark columns of ashes, and a blaze of light in the sky and on the water. Mr. Scrope's coloured engraving gives his artistic impression of the formidable eruption of A.D. 1822, with its mighty column of dust and vapour, expanding

horizontally at a height of some miles above the summit. The large brightly coloured Neapolitan drawings of eruptions in this century, and part of the last, are well known, and of much interest, though seldom executed with the precision which the large scale would have allowed. I offer a careful sketch in Plate XI.

The height of Vesuvius, the new cone, as compared with Somma, whose birth is pre-historic, has been carefully noted only in comparatively modern times. The height of the loftiest crest of Somma, the Punta del Nasone, has generally been assumed to be constant, viz. 3,747 feet. Another well-known point—a mark of the rise and fall of the crater of Vesuvius, called the Punta del Palo—is recognized on the northern slope, near the top, or else at the very edge of the crater, according to the state of this variable mountain. Its height is about 3943·6 English feet, according to a recent statement of Professor Palmieri.

Taking the proportions from some careful drawings, made at Naples, I judged the cone of Vesuvius, as it appeared in March and April, 1868, to be 500 feet above the highest crest of Somma. This gives 4,247 English feet for the summit of Vesuvius. In a recent valuable essay on the late eruption, Professor Palmieri has given this height at 1296·9 metres ≐ 4257·4 English feet. The highest eruption point being somewhat lower, viz. 1283·09 metres = 4209·6.

The Hermitage, on the north-west, may be taken at 2,080 feet; and the Pedimentina, on the south-west, at 1,600 feet.

Exact information on the height of Vesuvius does not go far back in the history, but the statements, though few, are of considerable interest.

For the first measure with the barometer we are indebted to the Abbé Nollet, who, in A.D. 1749, accompanied by Padre Della Torre, determined the height of the then existing cone of Vesuvius to be 3,120 French feet (1,014 metres). Singular to say, his companion on repeating the measure three years afterwards, with apparently great minuteness, and in several ways, arrived at the result of only 1,677 French feet (545 metres), a great error in defect. The cause of this mistake of a truly able man has not been investigated. I find that his observations give $23\frac{1}{4}$ lines for the barometrical difference between Vesuvius and the sea, the reading at the sea-level being 27 in. $6\frac{3}{4}$ lines. There was probably air over the mercury. The Abbé Nollet had found a difference of 40 lines.

Catani, in his Letter on the eruption of A.D. 1767, gives measures of Vesuvius, and states the height of the northern point at 720 canne, = 5,010 feet, of the southern 636 canne = 4,328 feet—a great error in excess.

Proceeding backward, we find in A.D. 1863, by Professor Schiavoni, 4,169 feet for the highest point of the mountain, and by a small photograph taken at Naples in December, 1861, the broad convex summit of Vesuvius appeared about 4,250 feet high.

In A.D. 1858, the highest point was a small lateral

cone, 20 metres above the usual central eruption point, and that was 1,240·1 metres=4,068·6 feet

20 metres= 65·6 „

4,134·2 feet.

A.D. 1857. The Admiralty charts give 4,100 feet for the summit of Vesuvius, 3,630 feet for the highest part of Somma, 1,952 feet for the Hermitage, and 608 feet for Camaldoli della Torre.

In A.D. 1855, the central eruption point being little different, the lateral cone was about 1,288 metres high, =4225·8 feet.

In A.D. 1850, the usual eruption point being nearly the same, the lateral cone alluded to was somewhat higher, viz. 1295 metres=4248·7 feet.

By another notice we find, on the 7th of March, 1850, 1,291 metres=4,235 feet.

In A.D. 1847, there was no lateral cone, the highest point being in the central eruption line 4068·6 feet, and in A.D. 1845, the eruption point was only 1181·7 metres high=3877·1 feet; but in the same vertical.

In A.D. 1822, Humboldt gave 4,022 feet for the summit edge of the crater: and 3,491 for its depressed part looking toward the south: but after the great eruption of this year was over, the maximum height, at the Punta del Palo on the north, was found by Mr. Scrope to be 3,829 feet, the minimum, looking toward Bosco Tre Case on the south, 3,346 feet. This last point is stated by Mr. Babbage to have been 3,400 feet high.

In this same year Lord Minto measured it 3,971 feet,

and Monticelli and Covelli 3,990, numbers which agree with the eye-sketch given by Mr. Scrope in his treatise on Volcanos.

In A.D. 1816, Visconti found it 3,971 feet.

In A.D. 1810, Brioschi records it 4,079.

In A.D. 1805, Humboldt and Gay Lussac 3,856.

In A.D. 1794, Breislak 3,920; and Poli 3,875.

In A.D. 1776, according to the careful drawings of Signor Fabri, in Sir W. Hamilton's great work, the height of Vesuvius proper must have been on a mean of two observations, 3,873 feet; and in A.D 1773, Saussure measured it to be 3,894 feet.

The following extract from Professor J. D. Forbes's Physical Notices of the Bay of Naples[d], will be found convenient for reference. The figures are from Humboldt. The toise is almost = 6·4 English feet.

'A. Rocca Punta del Palo. Highest N.W. summit above the sea.

					Toises.
Saussure, A.D. 1773, barometric measurement				..	609
Poli, 1794	,,	,,	..	..	606
Breislak, 1794	,,	,,	..	..	613
Gay Lussac, De Buch, and Humboldt, 1805	,,	,,	..	..	603
Brioschi, 1810, trigonometric measurement				..	638
Visconti, 1816	,,	,,	..	..	622
Lord Minto, 1822, barometric measurement				..	621
Scrope, 1822	,,	,,	..	..	604
Monticelli and Corelli, 1822		,,	..	..	624
Humboldt, 1822	,,	,,	..	..	629

Probable result, 625 toises (3,997 feet) above the sea, 317 toises (2,019 feet) above the Hermitage.

[d] Brewster's Edinburgh Journal, 1829.

B. LOWEST EDGE OF THE CRATER. (S.E.)

		Toises.
	1794, barometric measurement ..	559
Gay Lussac, De Buch, and Humboldt, 1805	,, ,, ...	554
Humboldt, 1822	,, ,, ...	546

Probable result, 553 toises above the sea.

C. HEIGHT OF THE CONE OF SCORIÆ IN THE CRATER, 1822, above the level of the sea.

Lord Minto, barometric measurement	.. ..	650
Brioschi, trigonometric measurement	.. ..	636
,, ,, ,,	.. ..	641

Probable true height, 646 toises, equal to 4,131 feet.

D. PUNTA NASONE, highest part of Somma.

Shuckburgh, 1794, barometric measurement	..	584
Humboldt, 1822	,, ,, ...	586

Probable height, 585 toises, equal to 3,741 feet.

E. ATRIO DEL CAVALLO.

Humboldt, 1822, barometric measurement	..	403

Equal to 2,577 feet.

F. FOOT OF THE CONE OF ASHES.

Gay Lussac, De Buch, and Humboldt, 1805,	barometric measurement ..	370
Humboldt, 1822	,, ,, ..	388

General base, 379 toises, or 2,524 feet.

G. HERMITAGE OF ST. SALVATORE.

Gay Lussac, De Buch, and Humboldt, 1805,	barometric measurement	300
Lord Minto, 1822	,, ,, ..	308·9
Humboldt, 1822	,, ,, ..	307·7

Probable height, 305·5 toises, or 1,954 feet.'

'Humboldt has no doubt that in the period A.D. 1816–22 the height of the Rocca del Palo had been about 12 toises higher than during the period A.D. 1773–1805, which he considers a singular proof of gradual internal elevation.'

The agreement of these data for the northern part of the summit of Vesuvius is remarkable; and seems to show that we may entirely depend on the constancy of level of the crest of Somma, and the Punta del Palo of Vesuvius, when that can be recognized. This last-named point is frequently buried in ashes, and, as now, quite overtopped by the accumulations of the higher cone: but these have in no instance risen more than 300 feet above the Punta del Palo. In no case, so far as we know, has the central crateral area been depressed more than in A.D. 1822, when it was estimated at one time to be 2,000 feet below the Punta del Palo, and measured at another later time (when partly filled by disintegration), at 800 feet (Babbage), and above 700 feet (Scrope).

In future times all the changes of height in every part of the mountain may be accurately recorded in photographs; and some assistance is already afforded by the accidental application of this process to particular phænomena. It appeared to me, however, that more systematic and thoughtful application of this beautiful art to preserve trustworthy outlines of Vesuvius, from selected and carefully-recorded stations, might be fairly pressed upon the skilful artists of Naples.

The good effects which have followed the establishment of Magnetic and Seismometric Observatories on the mountain and at Naples, under the guidance of Palmieri, must be mentioned with highest praise; and it may be permitted to hope, that the fragments of old Somma, on which stand the Hermitage and the Observatory, may not be speedily overwhelmed by the lava-currents which

several times have swept round them, and filled the neighbouring valleys, in spite of San Salvatore.

The structure of Vesuvius, the way in which its very numerous component parts are laid together and in some degree bound together, may now be considered with some hope of clearly understanding it. In the first place, let us remark the fact, everywhere visible, of the layers of the deposits—the conical stratifications which dip away from the axis. This is seen everywhere, as a rule, and admits of exceptions only within the central funnel, or lateral funnels if there be any. Next it is to be observed that this lamination increases in steepness as we ascend the mountain, up to a certain angle (about 30°), beyond which, except for short distances, the inclination is not augmented. Thus toward the base of the mountain on any side, the angle of inclination of the broadly extended deposits may be about 5°; and again, there may be parts near the summit of equally moderate dip, and much smaller extent. Wherever natural sections can be examined, it is found that the determining elements of this conical stratification are a mass of what was once volcanic dust, or small stones (lapilli), or lumps of scoriæ, such as are observed to fall in showers in almost every eruption, and in all directions round the smoke-funnel of the volcano.

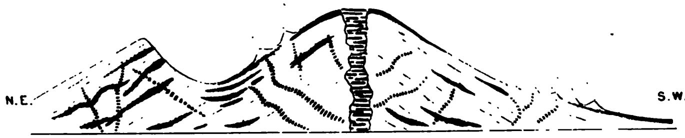
Such materials collected under the influence of gravity, and coherence arising from their various figures, settle to rest at any slope less inclined than that which may be called the angle of rest; and that

does not much exceed 30°, which is the maximum slope, for any considerable lengths, of the surface of Somma and Vesuvius, as well as of their interior layers.

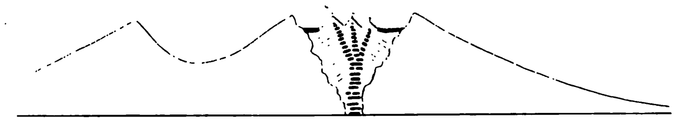
Mixed and alternating with these aërial deposits, if we may so term them, are sheets of solid rock, more or less parallel with the other layers, but neither so extensive, nor so regular, often sinking into hollows, or prominent in irregular swellings; not real strata, but masses which have taken in some degree the shapes and slopes of the other materials. These are the 'lavas,' or streams of once liquid rock: very similar in general to the products which are now poured out from the top or side of Vesuvius and other volcanos. Besides these, another element appears in the structure which crosses the strata and lava-sheets in various and irregular ways, and seems to fill extensive but narrow fissures in them. The substance of these dykes, as they may be called, is like that of the lava-sheets,—it is in fact lava which has been pressed, melted, into fissures of previously consolidated lava, and layers of volcanic dust and lapilli. They may not now be seen to be connected with a central stem of lava in the funnel, but they were so at the time of being injected among the other materials.

If we conceive of these fissures as having reached at any time the surface of the cone, and to have thus given free passage to the lava, they would become 'mouths' through which the currents would spring, and from which they would flow. A fissure of some considerable length might thus give origin to several or to many

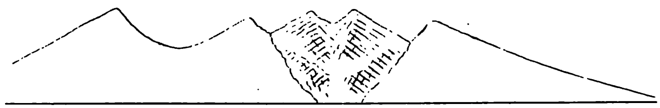
Pl. III.



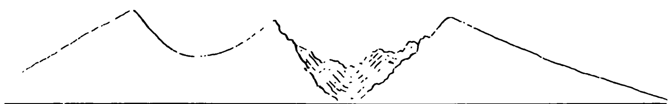
1868



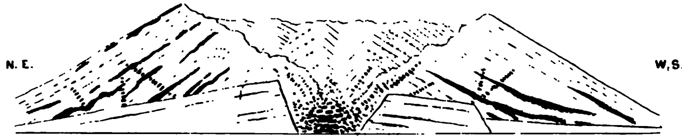
1843



1828



1822



J.P. del^t J.W.L. sc

mouths, all giving out lava, into one stream, as actually has happened on several occasions, as in A.D. 1760 and 1794. All the circumstances which have been stated may be readily apprehended by examining the vertical section through Vesuvius, given at the top of Plate VI, where fine dotted lines represent more or less continuous laminated stone and dust-beds, strong black spaces the less continuous lava-sheets, and the black dotted bands correspond to the 'dykes,' which on one side of the cone, above the Atrio, give origin to small vents, and on the other side, above Torre del Greco, combine in a row of mouths, such as actually deluged that town with a flood of melted rock. In the central funnel the parent stem of all these dykes is represented as continuing downwards into the deep parts of the earth.

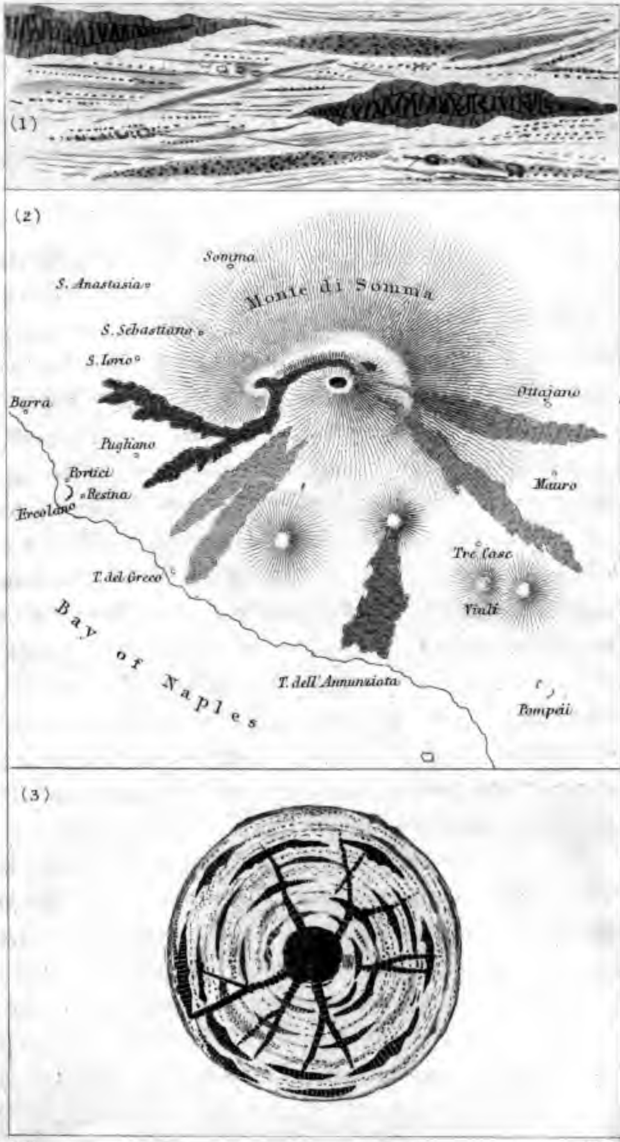
The other outlines on the same Plate correspond to particular occurrences of interest in the growth of Vesuvius. At the base is a representation of the structure as it probably was in the days of Spartacus, where in the vast crateral space, under the 'level plain,' was a mass of once loose dust and lapilli, gathered into conical slopes,—perhaps related to more than one vertical axis. These up-fillings, the fruit of many ejections and much disintegration, must have had some layers sloping from the containing walls, such as may be now seen in hollows of Somma, others inclined from the central funnel, and perhaps other funnels of less persistence. Under all these ejecta, and under the whole of the masses which had been thrown into the air and gathered into a truncated cone, there must be repre

sented a subjacent and far earlier mass of deposits,—beds composed indeed of volcanic ingredients, but arranged under the influence of the waters of the sea, and afterwards uplifted, broken into fissures—the origin of the volcano.

Above this is the idea which may be formed of the state of the great crater, left by the terrible eruption of A.D. 1822, at first 2,000 feet deep, and afterwards partly filled up to above half that depth by degradation of the sides and small ejections from the interior, with slopes of laminæ dependent on these two conditions.

In A.D. 1828 this old crateral surface was covered by new ejections, and a new crater-cone arose, to be again modified. In A.D. 1843 the top was nearly plane, with one, two, or three eruptive cones, surrounded by a circular ring of lava. So variable are the appearances within the crater, so frequent the repetitions of hills formed and again ejected; so changeable the points of efflux of lava, now from the summit, then from the sides, and almost from the base, by single mouths, or long fissures,—yet so simple the law, and so sure the result of the process employed by nature, 'constant in her ceaseless change.'

The structure of the Vesuvian cone is further laid open in vertical sections toward the base. These being parallel to the axis of the cone, and cutting the layers in a direction at right angles to those in the section through the axis, show all the layers level or approaching to the level position. They are seldom extensive enough at one place to give more than means of ap-


(1)
(2)
Somma
Monte di Somma
S. Anastasia
S. Sebastiano
S. Iorio
Barra
Ottajano
Pugliano
Portici
Resina
Ercolano
Mauro
Tre Case
T. del Greco
Bay of Naples
T. dell'Annunziata
Pompeii
(3)

J.P.

J.W.L.

proximation to a correct view of the facts; but by comparing several sections—such as occur along the line of railway between Portici and Torre dell' Annunziata—the evidence becomes satisfactory. We learn that the beds of lava are for the most part of small horizontal extent, and in general of no great thickness. Each is a narrow stream, imbedded in a greater mass of aërial, or in some cases aqueous deposits; each being usually covered by, and also resting upon, a scoriaceous mass, which is of the same nature as the true lava, chemically speaking, and only different in texture by circumstances during the movement of a current which affected the surfaces more than the centre of the mass of fluid rock.

From these sections, one through the axis, and another parallel to the axis, which may be regarded as real, we may now proceed to a third, which, though ideal, or rather a matter of inference, is quite as true and certain in its meaning as the others. This is the horizontal section at right angles to the axis of the cone.

In the drawing to represent this horizontal section, see Plate VI, we observe the general concentricity of all the layers of lava, marked black, and of the deposits of loose materials of varying aspect. None of these are really continuous round the mountain axis, though on the average of long time the granular materials which compose the far greater portion of the mass are nearly in equal quantity all round. The fissures which cross the laminæ are not necessarily *seen* to be connected with the central pipe through which the lava rose, either in the vertical or horizontal sections; but they

may be safely inferred to be so, or at least to have been so.

We may now transfer our attention to the surface, and consider the distribution of the very numerous streams of lava which ran down from the summit, or some part of the slope of Vesuvius. The first attempt to lay down the lava-currents on a map which has occurred to me, is an excellent specimen of Sir W. Hamilton's well-directed attention. On Plate VI this map is copied, and it may be seen that the lavas marked are those of four years specially noted; viz. A.D. 1737, from the south-west side of Vesuvius, which ran toward Torre del Greco; A.D. 1760, which started at a mouth low down on the south side, and reached to the sea-side near Torre dell' Annunziata; A.D. 1767, which began on the north side of Vesuvius, flowed in a curve far down the Atrio, and then descended on the south side of the Salvatore toward St. Giorio; and A.D. 1771, which rushed down toward Resina. Two other currents, proceeding eastward toward Ottajano, and south-eastward between Tre Case and Mauro, have no dates assigned by Hamilton,—they belonged to the eighteenth century. This map may indeed be regarded as illustrating the best-known lava-currents between A.D. 1700 and 1771. It would not have been an easy task for even this author, who had ascended Vesuvius more frequently than any one but the guides and labourers, to have traced the earlier currents.

The map constructed by Necker, and printed in the Memoirs of the Nat. Hist. Soc. of Geneva, vol. ii.

pt. i. Plate I. A.D. 1823, contains various currents of earlier date than A.D. 1820. Commencing our remarks on the north-west side, we see the short currents of A.D. 1786, in the Fosso del St. Sebastiano and the Fosso Vetrana; next the long stream of A.D. 1767, rushing down the Fosso Grande toward Portici; then the lava of A.D. 1631, which flowed across that place. The current of A.D. 1779 next appears, directed between Torre del Greco and Portici; this is followed by a branch of the lava of A.D. 1631, to Torre; then by lava of A.D. 1820; and finally, this series ends in the stream of A.D. 1794, which crossed through Torre del Greco. The long currents of A.D. 1737, 1760, and 1751, flowing south-west, south, and south-east, bring us round to the south end of the Atrio del Cavallo, and there we have the lava of A.D. 1817. Thus a figure something like the half of a many-fingered star-fish is made, not a single stream being directed to the north-eastern region, over or through the steep ridge of Somma.

The great national Survey next claims attention, on account of the attempt to delineate on it the principal masses of lava in their actual extent, on a large scale (about $\frac{1}{25000}$ of nature). The crater is represented as it was in A.D. 1862 (see Diagram, p. 202), and between this date and A.D. 1631 some of the many streams of lava are represented. The most striking feature perhaps is the great lake, as it may be called, of melted rock which has gathered at the foot of the cone, on the west and north-west, above the Fosso Grande and the valley

near the Hermitage; and the still more ample sheets which serve as buttresses above Bosco Tre Case, on the south-east. Almost every eruption has added to these large areas.

The map of M. Le Hon, published in A.D. 1866, represents in colours, on the scale of the national map, the courses of all known currents to A.D. 1861, as well as the frequent superposition of one on another will allow, and the result is a most useful guide to the student.

The maps of the Survey and M. Le Hon[e] are the best authorities for currents as far back as the expanded streams of A.D. 1631,—which, with the amazing showers of ashes accompanying them, have in fact obscured almost all the superficial traces of earlier eruptions. In the map prefixed to this volume, I have arranged such materials as could be found, in periods; different colours being employed to indicate the lavas of successive periods.

By reference to this map, the copy from Hamilton, Plate VI, and the diagrams farther on in this chapter, the growth of the whole mass may be understood, and some important general views may be considered.

First, we remark how small a portion of the half-circular space around Vesuvius is left uncovered by lava-currents of one age or another: these currents for the most part followed natural hollows in the surface, which had been left between the upstanding ridges of earlier currents. By the solidification of one current

[e] This map was published in 1866, but was hardly to be procured in Naples in March, 1868.

the way in that direction was often blocked against a later one. Not always so: for in some cases the valleys to be filled in the course of some currents were deep enough at the beginning to absorb all the streams that fell into them, and still leave space for more. This was the case with the deep ravine on the south of the ridge of St. Salvatore, the Fosso Grande, and the Fosso della Vetrana with its two forks north of that ridge. So the Fosso Bianco above Torre del Greco, and the valleys which margin Monte Ottajano, have received many streams, and have still room for more. These deep cavities have often arrested the lava-currents and saved the sea-coast towns from destruction.

The only part of the great circle round Vesuvius which appears free from the currents is the old mountain of Somma. On a first view from the Atrio one looks at that great mass much as the Trojan hero regarded the Latian city:—

> 'Aspicit urbem
> Immunem tanti belli, atque impune quietam.'

It is so different in its grim repose from its restless neighbour, that one is disposed to regard it as a portion of the earlier earth, solidified under pressure and raised by a mightier agency than volcanic effort or earthquake vibration. Such to many eminent geologists has appeared to be the true origin of the whole mountain, an example of 'an uplifted crater'—raised by subterranean pressure directed to a point, the strata all yielding to this pressure round a vertical axis, so as to dip in all directions from the centre. Certainly, the first aspect

of the old rocks of Somma,—masses of lava, tufa, and consolidated stones, scoriæ, and dust—many laminated, others more or less regularly bedded (see Diagrams XX, XXI),—this first aspect lends no little colour to the hypothesis of 'Erhebungs-Cratere,' as applied to this example.

But when we consider the nature and arrangement of these beds and laminæ, and compare them with the sections at the seaward base of Vesuvius,—sections which lay open the unequivocal lavas and ashes of definite eruptions of historical and even modern date (see Diagrams XXII, XXIII),—we perceive that the differences, though real, are not greater than may be fairly ascribed to time and peculiar conditions. In another place we shall examine some of the points of general theory involved in the question of elevation-craters, and endeavour to assign the limits of its application.

Returning now to the surface of Somma, we see it to be ridged and furrowed in the same radiating manner as the slopes below the eruptive cone. The general effect of the ridges and hollows may be seen on Plate I, and on the coloured Plate the reader may supply for himself the obvious inference that in a primary sense the ridges and valleys of Somma, however much they may have been modified by descending rains and torrents, have the same constitution of lava-currents and ashy upfillings as the similar inequalities on Vesuvius. If we join to these considerations the important fact of the agreement in slope between Somma and Vesuvius,

we shall not easily be driven from the conclusion that the parts of these mountains which we see were formed in the same manner. There was formerly but one Vesuvius, and apparently only one volcanic axis has ever been in action here.

But we do not see all the inner and lower parts of the mountain, and there are circumstances which appear to favour the opinion of great movements having happened in and about it, which no volcanic excitement and no earth-tremor can explain.

If a line be drawn by the elevated ends of the crescent ridge of Somma, it will, if continued to the north-westward, pass close by and leave on the south the old volcanic tract of the Phlegræan fields. This line nearly coincides with the valley of Massa di Somma and St. Sebastiano, and with the ridge of the hill of Ottajano. Neither the escarpment on the north-eastern side of the valley of Somma, nor the ridge of Ottajano, can be at all explained as due to lava-currents, or any form of volcanic action. They appear to have been produced by something of the nature of a great fault, dislocating the strata on the line mentioned. On such a fault-line atmospheric vicissitude has been effective in the valley of Somma, and volcanic ejections have operated on the other. Both, it is probable, had acquired their main features before the occupation of Spartacus, who may have found the Fosso della Vetrana too closely watched by Clodius, and made his escape down the opposite slope. On such a line of weakness, occasioned by ancient fissures, the volcanic violence of A.D. 79 burst with

destructive force; the western side suffered most, and was most depressed after the eruption, probably because it was originally more cross-fissured than the other, as the Fosso Grande and Fosso Bianco remain to indicate, and so became an area of less resistance. That it has always been the weakest side since that eruption is clear from the outbursts of lava and ashes from mouths below the Pedimentina, A.D. 1760, 1794; that it may have been so before that day the Camaldoli hill, and the hills about Viulo, appear to indicate.

This appears to be the most probable view of the cause of the entire immunity of Somma; while eighteen centuries of violent eruption have devastated the other half of the mountain country.

If it were objected that such a case of fracture nearly through the axis of a volcano requires the support of another example, we might reply that a great example occurs in Auvergne, through the rocks under the cone of ashes and lava called the Gravenoire; and that the moon, in her grand 'Phlegræan field,' gives several notable instances. In these cases, no doubt, the fault may have happened before the volcanic action was set up: it may have been the cause of its being set up in the place where it is, but so it may have been in the case of Vesuvius, and a second disturbance may have happened on the primitive fissure.

The extent and form of the crater of Vesuvius, meaning by this term the whole concavity of the summit—·ithin which small cones very often appear and grow to the full size of the encircling crest—have been

very often vaguely noticed, but very seldom exactly described. The earliest detailed map of the crater and cone of which I am informed is that of M. Necker, already referred to, pp. 192–3. In this map the crateral top is of an oval shape, the long axis lying from west

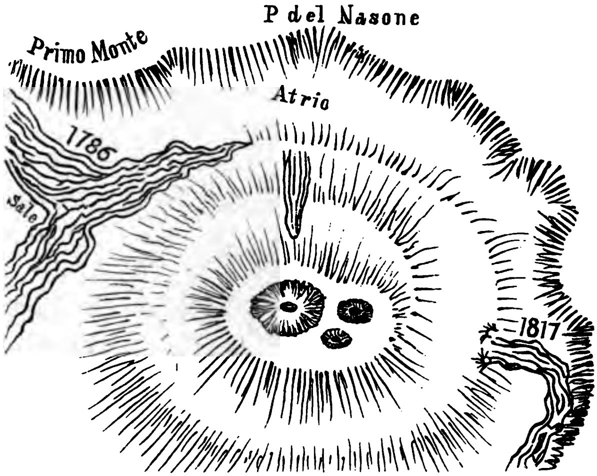


Diagram XXIV. MAP OF VESUVIUS IN 1820.

to east, about five-eighths of a mile (1,100 yards) in length [f]. Within it are three 'voragini' nearly filling the area. The epoch of this drawing is April, 1820. The lava-currents are marked by dates, 1786 and 1817.

Professor Guiscardi has published a plan of the crateral top taken in A.D. 1855, which shows a nearly circular

[f] In 1822, after the eruption, the crateral diameter was about three-quarters of a mile (1,320 yards).

top to the mountain, and within it two considerable craters which were formed in A.D. 1850 (*b* and *c*), on the eastern and southern sides, with a lava-covered hollow on the west and north, and a small deep 'voragine' (*e*) nearly under the Punta del Palo (*a*). An outflow of lava is represented on the north-west.

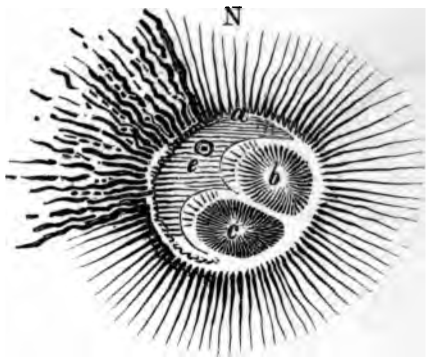


Diagram XXV. MAP OF THE CRATERS, 1855. *a.* Punta del Palo. *b.* Crater of 1850. *c.* Ditto. *e.* Voragine, 1855. The lines under *a* represent fissures across stratified deposits.

The small deep crater on the north-west being taken at 80 metres over, the mountain top would be between 500 and 600 metres over, and the old hemispherical concavities, left from A.D. 1850, about 300 metres. These measures indicate the diameter of the mountain top to have been about 600 yards.

The map of M. Le Hon, which brings down the information to the year 1861, assigns a nearly oval

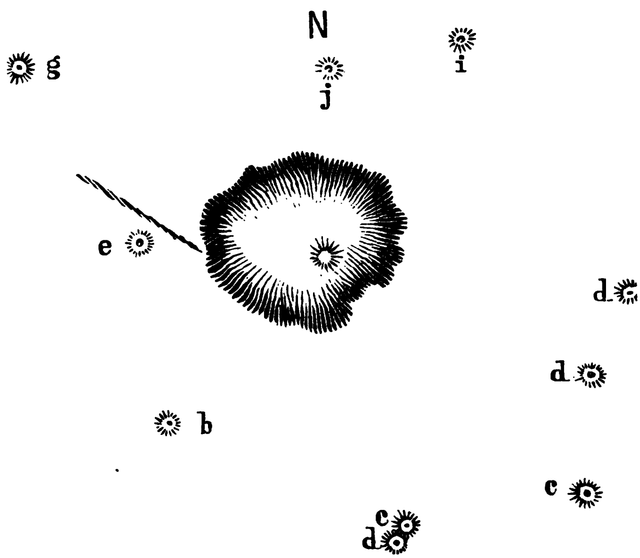


Diagram XXVI. SUMMIT OF VESUVIUS, 1861. *b.* Bocca of 1737. *cc.* Bocce of 1751. *ddd.* Bocce of 1754. *e.* Fissure of 1767. *g.* Fissure of 1820. *i.* Fissure of 1850. *j.* Fissure of 1855.

crater, the long axis from east to west, with a small interior one in the eastern focus. The largest diameter was about 750 yards.

The national Map represents a crater with the date of A.D. 1862 attached, nearly circular, with a small hollow on the edge of the eastern side; the diameter one-sixth of a geographical mile, or about 340 yards. The several 'bocce' of the currents of A.D. 1855, 1856, 1858, and the fissure of A.D. 1767 are marked by the dates.

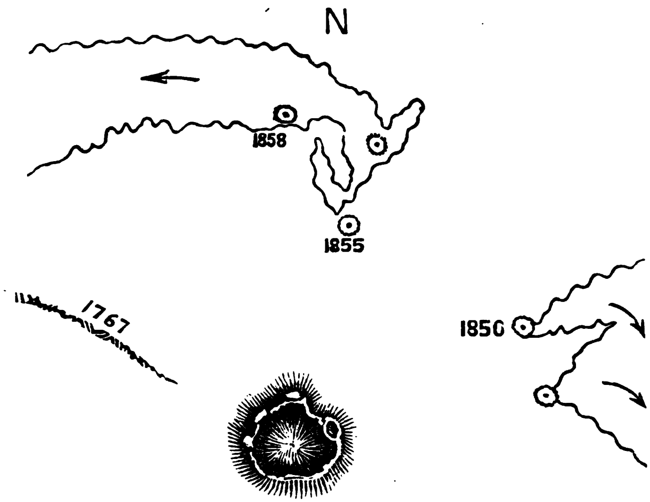


Diagram XXVII. Summit of Vesuvius, 1862.

CHAPTER VIII.

THE PHLEGRÆAN FIELDS.

'Hic genus antiquum Terræ, Titania pubes,
Fulmine dejecti, fundo volvuntur in imo.'

VIRGIL, *Æn.* vi. 580.

THE conical mass of Vesuvius rises solitary in the large Campanian plain; a vast heap gathered round a vertical chimney, during the course of the latest geological time. Seen from afar, the blue dome, crowned with white cloud, rises over the plain and over the sea like the dream of a painter; by nearer approach it grows to a mighty beacon, reared by nature to warn, perhaps to protect, the people who have clustered round its fires. There is reason to think that through many uncounted periods, each as long as the historical age of Vesuvius, this safety-valve for the volcanian pressure has been the principal channel to the surface, but it has not been the only one, nor was it, probably, the earliest of many. Looking to the west, the eye ranges from Vesuvius across the Bay of Naples, toward a group of crateriform hills and cliff-girdled lakes, whose origin

is volcanic, and whose date is various—some probably far older than Vesuvius, others historically known to have been in eruption only a few centuries ago. This is the region of the Campi Phlegræi, rendered famous by the admirable work of Sir W. Hamilton bearing this title[a]. In this district two eruptions are on record: that by which the Monte Nuovo was raised in A.D. 1538; and that which came from the Solfatara in A.D. 1198. The first-named was principally an eruption of ashes, the other was marked by a small and short current of lava—one of the few occurrences of this kind in the whole Phlegræan tract.

The Campi Phlegræi and the ancient cities established on the neighbouring coasts are frequently referred to by Greek and Roman writers, especially by the poets, who have preserved the myths or traditions connected with its ominous lakes, hot springs, and sulphureous vapours.

The name is Greek, Φλέγρα, (φλεγυρὰ, ardent, burning), and was applied to several tracts which either showed traces of ancient earth-fire, or were celebrated by tradition as places where the giants were overthrown by lightning from heaven. One of these places was in Macedonia, and it is possible that the lines of Propertius,—

> 'Te duce vel Jovis arma canam cœloque minantem
> Cœum et Phlegræis Oromedonta jugis[b];'

[a] Naples, 1776, with supplemental letter to Sir J. Banks, Oct. 1, 1779.

[b] Prop. iii. 7. (9.) 48.

and those by Ovid,—

> 'Cecini plectro graviore gigantas
> Sparsaque Phlegræis victricia fulmina campis [c].'

But 'Gigantea litoris ora' (Prop. i. 20. 9) must refer to the Cumæan shore.

Ovid, after describing the course of the Trojan hero, with his fleet, sailing northward, from Sicily, by Leucosia and tepid Pæstum, notices but does not employ the name of the Phlegræan fields:—

> 'Inde legit Capreas, promontoriumque Minervæ,
> Et Surrentino generosos palmite colles,
> Herculeamque urbem, Stabiasque et in otia natam
> Parthenopen, et ab hac Cumææ templa Sibyllæ.
> Hinc calidi fontes [d].'

The course of the voyage is the same in the Æneid,—from Sicily by Misenum, toward the north:—

> 'Et tandem Euboicis Cumarum allabitur oris.'

The Sibyl is consulted, and the Stygian descent accomplished by the route of Avernus:—

> 'Spelunca alta fuit, vastoque immanis hiatu,
> Scrupea, tuta lacu nigro, nemorumque tenebris:
> Quam super haud ullæ poterant impune volantes
> Tendere iter pennis: talis sese halitus atris
> Faucibus effundens, supera ad convexa ferebat:
> Unde locum Graii dixerunt nomine Aornon [e].'

The first historical notice of this remarkable tract of country is from the accurate hand of Strabo; and it is sufficiently in detail to admit of strict comparison with the existing shores, lakes, and hills.

[c] Metam. x. 151. [d] Ib. xv. 709.
[e] Virg. Æn. vi. 237.

'Between the promontories of Misenum and Athena is the large bay called the Crater. Along this shore lies Campania, of all plains the most delightful: surrounded by fertile hills, and the mountains of the Samnites and Oscans. Antiochus tells us that it was inhabited by the Opici, also called Ausones. But Polybius regards them as two different nations, who dwelt in the country round the Crater. Others relate that after its occupation by the Opici and Ausones, the Oscan people held it, till they were driven out by the Cumæans, who yielded to the Etruscans; but on account of its rich character, the possession of the territory was vehemently disputed. Samnites succeeded, and Rome absorbed all.

'In this fertile region, corn of the best quality grows; from which alica is prepared much superior to that of rice or any other grain. In some parts of Campania, zea is grown twice, then a crop of panicum, and afterwards salad—four crops in the year. From this country the Romans receive their choicest wine,—Falernian, Statanian, Calenian, and Surrentinian, which is not inferior to them, and has lately been proved to bear keeping. Nor less abundant in the olive is the whole tract of Venafrum, which adjoins the plain.

'The cities of Campania,—Sinuessa, Linternum, after these Cumæ, the very ancient work of the Chalcidensians and Cumæans, the oldest city established by Greek colonies in Sicily or Italy. The commanders of the expedition, Hippocles of Cumæ, and Megasthenes of Chalcis, agreed that the colony should be called by one of these names, the city by the other. So the city

is called Cumæ, though it seems to have been erected by Chalcidensians. From the beginning fortune favoured the city: the fables regarding the Phlegræan fields and the combats with giants having no other origin than the richness of the land, which led to many contests for the possession of it.

'After doubling Misenum,' he says, 'next comes a lake [f], beyond which the coast falls back in a deep bay, where stands Baiæ with its warm baths, suitable both for luxury and for the cure of diseases. The Lucrine lake borders upon Baiæ; within it is lake Avernus, which makes the tract from Cumæ to Misenum a peninsula. Here our ancestors placed the scene of Homer's Nekuia in the Odyssey; where they say was an oracle, where answers were returned by the dead, to which Ulysses came.'

Avernus he describes as 'a deep bay with a narrow entrance, in size and shape well suited for a harbour, but rendered unfit for that purpose by the broad shallow Lucrine basin which lies before it. It is inclosed by steep ridges, which overhang it everywhere, except at the entrance, now highly cultivated, but formerly covered by a trackless forest of large trees, which threw a superstitious gloom over the hollow. The inhabitants further fabled that the birds which attempted to fly over it fell down into the water, destroyed by the rising exhalations, as in other Plutonian places; and regarded

[f] This may be the almost circular sheet of water, now called Mare Morto, or the equally circular Porto di Miseno; both, it is probable, remains of volcanic craters of great antiquity.

Avernus as sacred to Pluto, and the abode of the Cimmerians.

'Whoever entered this lake, first adored the subterranean deities, by the aid of priests for the purpose.

'Here is a fountain of fresh water by the sea; but all persons abstain from it, believing it to be the Styx; and somewhere near was the oracle. Here also, as they supposed, judging from the hot springs near Acherusia, was the river of fire (Pyriphlegethon).'

Ephorus speaking of the Cimmerians, says they inhabited subterranean chambers, called argillæ (ἄργιλλαι), communicating with one another, by ways through which persons were led to the oracle, deep underground. They obtained their living by mining and the oracle; never seeing the sun, but coming out of their earth-dwellings by night. Such were the fables of an earlier age, but rejected in the time of Strabo, and disproved when Agrippa cut down the forests which surrounded Avernus, and dug a tunnel between it and Cumæ.

'The Lucrine lake in breadth reaches to Baiæ, being separated from the sea by a mound, about a mile (eight stadia) long, and wide enough for a broad carriage-road, said to have been made by Hercules as he was driving the oxen of Geryon. Being much exposed to the waves, in storms, so as not to be easily traversed on foot, Agrippa raised and completed it. The Lucrine admits light ships, and though useless as a naval station, affords an inexhaustible supply of oysters. This, according to some, was the lake Acherusia, but Artemidorus makes it the same with Avernus.

'Next to Baiæ come the shores and city of Dicæarchia, formerly a port of the Cumæans, placed on a hill. During the invasion of Hannibal, the Romans colonized, and called it Puteoli, from the numerous wells; or, as others say, they so named the whole district, as far as Baiæ and the Cumæan territory, from the stench of its waters, because it is full of sulphur, and fire, and hot springs. Some think this is the reason why the country about Cumæ is called Phlegra, and that the wounds of the thunder-stricken giants pour out these streams of fire and water.

'This is a city of great trade; and has artificial wharfs for ships, for the construction of which the sand of the place mixed with lime is remarkably adapted, by its speedy solidification. In this way they carry moles into the sea, and make places of shelter on the open coast, for large trading vessels.

'Immediately over it is Vulcan's assembly-room (ʽΗΦΑΙΣΤΟΥ *ἀγορὰ*), a level space surrounded by fiery heights, having numerous chimney-like spiracles, which throw up fire with great noise; and the level interior is full of ductile sulphur.'

This is the crateriform hill called the Solfatara, which, in all points except the burning walls, agrees remarkably with the description of Strabo.

'Beyond Puteoli is Neapolis, first occupied by the Cumæans: then afterwards some Chalcidensians, Pithecusians, and Athenians came, and the name Neapolis was adopted: here is seen the monument of Parthenope, one of the Syrens, and gymnastic contests are held

according to the direction of the oracle. Still later, Campanians were admitted among the citizens, as the magistrates' names prove, for these, at first all Greek, were afterwards partly Campanian and partly Greek.'

Strabo then observes that many Greek customs remained in Neapolis, describes the arched tunnel through the hill on the road to Puteoli, and speaks of the fountains and baths, and of the frequent resort of Romans for enjoyment of leisure, or the charms of climate and easy life.

(Some years later Nero, fearful of making his *début* as an actor at Rome, appeared on the stage of this old Greek city [g].)

The excellent author from whom we have quoted so much, then gives the account of Herculaneum, Pompeii, and the Vesuvian slopes, to which attention has already been called at p. 5. He concludes his survey of the Bay of Naples, after having described the promontory which terminates the coast of Sorrento, with these remarks: 'And here ends the bay, which is called the Crater, enclosed between the two promontories, Misenum and Athenæum, which look to the south; everywhere enriched with the cities which have been named, with villas, and cultivation, so closely adjacent as to present the appearance of one continuous city.'

Such is the smiling aspect under which it is viewed to-day; and such the wealth of perpetual natural advantages in the land of Circe and the Syrens, Avernus

[g] 'Non tamen Romæ incipere scenas ausus, Neapolin quasi Græcam urbem delegit.' Tac. Ann. xv. c. 33.

and the Cimmerians, which are the fruit of frequent earthquakes and occasional eruptions.

In the Phlegræan fields, the one spot which displays somewhat of the continuous effect of subterranean heat is the Solfatara, a rudely circular space, hollowed like a dish, within steep irregular slopes of crumbling tufaceous, pumiceous, and trachytic rocks. Hollow sounds answer to your footsteps on this somewhat alarming surface, which is pitted over by artificial diggings, and broken by natural chasms. From the most remarkable of these, under rugged cliffs, about a hundred feet high, on the eastern side, rises a mingled column of aqueous vapour, sulphuretted hydrogen, a small quantity of muriatic acid gas, and a little muriate of ammonia.

These were detected by Dr. Daubeny in A.D. 1825, who has explained the effects produced by them on the compound siliceous aggregates which form the trachyte of the Solfatara; the final result being the deposition of sulphur and the formation of sulphuric salts, viz. sulphates of iron, lime, soda, magnesia, and alumina. Sulphur, with some arsenical sulphurets, is found diffused in crevices of the rock: not probably by original sublimation, though that explanation suggests itself, but as a result of the process mentioned in the note below[h].

[h] By union of the sulphuretted hydrogen with the bases of the earths and alkalies in these trachytes, hydrosulphurets would be formed. Compounds of this class, when exposed to air and moisture in presence of carbonic acid, undergo decomposition; the bases are oxidated and combine with the acid; the sulphuretted hydrogen is resolved into its elements; sulphur is partly separated and partly converted

The white efflorescent saline plain of the Solfatara well deserved the title of the Campi Leucogæi; the most prevalent of the salts is the sulphate of alumina, the basis of alum, which was extracted in considerable quantities in the last century, by merely washing, and boiling, and crystallizing. Sulphur was collected, by the contemporaries of Pliny [i], from the same area, which thus merited another still characteristic name, the Forum Vulcani.

The Solfatara is in the condition of long decay, a half ruined and degraded volcanic vent; but while its fumaroli remain we can hardly regard it as quite extinct. It is on record that one eruption happened from the southern side of the hill, and gave a current of lava, which ran continuously toward the sea, and covered the ancient cemetery on the Via Puteolana [k], and now forms the promontory called Monte Olibano. It is a gray trachytic current, mostly felspathic, with very little augite; but reddened in places by oxide of iron or ochre. The current is, as usual, scoriaceous above and below.

Exhalations of sulphur appear in some other parts of the Phlegræan region, one of the most remarkable situations being near the eastern edge of the Lake of Agnano, which fills an old and degraded volcanic crater.

into hyposulphurous acid, and water is formed by the hydrogen uniting with atmospheric oxygen. Hyposulphuric salts also appear, but are not permanent; so that finally sulphur and sulphuric salts remain, as we find to be the case.

[i] Nat. Hist. lib. xxxv. cap. 50.

[k] Murray's Handbook for Naples, ed. 1865, p. 320.

The sides of this basin are irregularly steep and in part woody, or gently rising and covered by vineyards. It appears to be in a later stage of decay than the Solfatara. The bordering stratification is altogether tufaceous, mostly dipping outwards, and in places broken by faults or landslips of great antiquity. Vapours of sulphuretted hydrogen rise through fissures caused by such slips, with a temperature of 180° F.; they were employed for bathing purposes by the Romans, and are still resorted to under the name of Stufe di San Germano. Sulphur is collected from the fissures and crevices.

Near this point, in the Grotto del Cane, carbonic acid gas is slowly poured out from other fissures; and a larger quantity rises in bubbles through the water of the adjacent lake, which is only a few yards above the level of the sea. The issue of this gas has lasted for eighteen centuries, since it was well known to be deleterious, and was indeed employed as such by Tiberius; and we may readily believe the same to have been the case for as long a period previously. The origin of the carbonic acid gas is probably to be found in the calcination of limestone on the sides of some deep volcanic furnace.

Conspicuous among the old craters of the Phlegræan fields is that of Astroni, within which is the Royal Caccia, or hunting-ground. Here, enclosed by a very steep ring of rocks, 3½ miles in circuit, wild boars and deer roam amidst forests of oak and ilex, and slake their thirst in small lakes half covered by water-lilies. These

lakes are but little above the level of the sea, and lie in a sort of atrio partially surrounding the central mass of the crater, which is a double-backed hill, containing some trachyte, but more tufa and ashes, with pumice and pitchstone. The high surrounding crest is composed of tufa, with pumiceous and pebbly bands, all dipping outwards, except where, as near the only entrance, a huge landslip has brought the rocks down to a slope directed inwards. According to the opinion of Von Buch and his followers this is a crater of upheaval ('Erhebungs-Cratere'); the strata round the axis dipping outwards every way, because of the uplifting force being vertical under this area; and the central trachytic bosses are supposed to have been pressed up, without overflowing,—unerupted lava, like the central trachytic cone of the Rocca Monfina.

But according to Lyell and his supporters, this outward dip of materials in conical strata, aggregated round a central boss of rock once fluid, is to be interpreted quite otherwise. It is to be explained as the natural result of many successive showers of ashes and eruptions of mud, round a funnel of volcanic energy, which at last became tranquil and full of rock consolidated from fusion,—a rock whose chemical nature is nearly the same as that of the surrounding tufaceous sheets, and which, had it been dissipated by the steam-power of nature, would have yielded those materials in the form which they have assumed.

No lava has been observed in the encircling sheets of the volcanic tufa of Astroni or Agnano: in this respect

they differ from the cone of Vesuvius and the crateral edge of Somma.

The rival hypotheses of the origin of the ancient Astroni encounter each other again on the margin of another crater which was produced only 230 years ago, by a short-lived eruption west of Pozzuoli. This cup-mountain is 440 feet above the sea at its highest point, while the small interior plain is only 19 feet above that level[l]. The sides are formed of tufa, in strata dipping outwards, and only in one part of the circumference toward the west is anything like a lava sheet to be seen. This, however, is seen, and it forms an undulated scoriaceous mantle on that side, from a few feet to a few yards in thickness. On the outer surface of the cone are many loose ejected small rough masses of scoria—trachytic for the most part.

The road which sweeps round the north side of Monte Nuovo leads to a view of Avernus so pleasing and picturesque as to surprise the student fresh from his books. An 'easy descent' indeed; open, nights and days, is now this 'janua Ditis[m];' nor is much labour required for the return to the road. A sketch of the prospect, from a point of this road which commands Misenum and Baiæ; the mole across the bay, the Lucrine lake, and the slope of Monte Nuovo, is pre-

[l] These measures, taken by Mr. Lee and myself in 1868, agree exactly with previous publications.

[m] The building on the left (eastern) part of the sketch is often called by the guides 'Temple of Pluto;' it was really a bathing establishment of Roman date.

sented below, and it awakens reflections which have a bearing on geological theory.

We remark, in the first place, the calm dark water, nearly level with the sea, and 250 feet deep; its circular border of laminated tufa, commonly steep and in places

Diagram XXVIII. VIEW OVER AVERNUS TO MISENUM. (*Original.*)

broken into prominences and recesses. No sign of life on its waters; no birds flying above; some remains of forests on the hill sides, but no great natural cavern such as the poet imagined for the Sibyl :—

> ' Dark was the cavern, wide its jaws of rock,
> By the black lake and woods of mighty shade :'—

nor any upstreaming mephitic vapour.

A crater of immense antiquity opened to the south, after having been 'cleared out' by a vast explosion; communicating with the sea perhaps, by the subsidence,

or dissipation in ashes, of its southern border; not permanently opened, however, for in the earliest dawn of history on this coast it is an enclosed lake separated from the sea. The separating low tract of land is still before us, through which Agrippa and the Roman engineers cut a ship channel to allow of the employment of the dreaded lake as a safe harbour for a large fleet. In this tract are still found remains of buildings connected with the ancient navigation. Beyond it, looking seaward, is seen a narrow sheet of water, still called the Lucrine Lake—though reduced from that expanse which anciently fed the best oysters of Italy; and then a narrow mound and road, which leads from Baiæ to Puteoli. This road and mound represent, though they do not replace, the ancient mole which protected the Lucrine from the sea. The Lucrine was connected with the sea by a continuation of the works which united it with Avernus. From comparing the ancient descriptions with modern appearances, it is probable that no very important changes have been produced in the levels or areas, or relative features of any of the places on this coast. Two or three thousand years at least have passed and left the Avernian region much as it was in the days when colonists first braved the real or imaginary terrors of the Phlegræan fields.

Yet only three centuries and one-third have completed their course since a terrible eruption shook the whole country, and raised a 'new mountain' on the eastern side of the Lucrine.

According to contemporary accounts, the whole coast

from Pozzuoli to Misenum was on this occasion subjected to risings and fallings, before the great eruption—risings of the shore so as to expose a part of the sea-bed 200 paces broad and kill the fishes. These risings were followed by more limited depressions, and then the volcano burst forth. The change of level on the coast corresponding to 200 paces of shore could not exceed

Diagram XXIX. MONTE NUOVO, from the shore of Pozzuoli. (*Original.*) The low ground on the right is called La Starza, believed to have been elevated in the course of volcanic excitement.

a few feet, or fathoms; but it is of importance to consider it in relation to the formation of the mountain. It shows that a greatly extended pressure was exerted under all this Phlegræan region, which was not satisfied till Monte Nuovo was formed. They who suppose the mountain-mass to have been 'uplifted' by the pressure, must necessarily also suppose the general pressure to

have been determined to a point vertically below the crater now observed. This implies previous dislocations or disturbances of some kind, most likely productive there of crossing or meeting lines of weakness. On such conditions the masses might be lifted, but they could not be lifted with the quaquâ-versal dips and continuous outlines which we see round the crater. All that we see in the Monte Nuovo is the fruit of eruption through a vertical opening. This opening may have been, must have been, made by pressure at a point, or on a line or small surface of weakness, and then, it is quite probable, a real displacement, a primary 'Erhebung,' may, or rather must have taken place. But the opening once made, the subsequent efforts were explosive; the ejected matters gathered round an axis of eruption; the seemingly concentric sheets were laid by successive ejections, not upheaved in a solid form by the local effect of a general subterranean pressure.

These inferences from mechanical considerations are found to be borne out by observations in the interior of the crater of Monte Nuovo. For here in the depth of the south-west extremity of the little cultivated plain, the stratified masses are not arranged at all according to what may be called the conical symmetry of ejection, but are dislocated and dip unconformably.

In descending by the path to the small central plain, steps cut in lava, or what seem to be such, are passed over.

Marine shells of existing species have been found in some of the masses which compose the cone of Monte

Nuovo, but whether they were upheaved in these masses, or ejected among the spolia of the sea, is not certainly known.

We are indebted to Sir W. Hamilton for the discovery and preservation of two narratives of the eruption of Monte Nuovo by contemporary witnesses of credit, published a few months after the event. These narratives, bound in one volume, were presented by Sir W. Hamilton to the British Museum.

The title of the first is Dell' Incendio di Pozzuolo [n], Marco Antonio delli Falconi all' Illustrissima Signioria Marchesa della Padula nel MDXXXVIII.

The following is Hamilton's translation:—

'First then will I relate simply and exactly the operations of nature, of which I was either myself an eye-witness, or as they were related to me by those who had been witnesses of them. It is now two years that there have been frequent earthquakes at Pozzuolo, at Naples, and the neighbouring parts; on the day and in the night before the appearance of this eruption above twenty shocks great and small were felt at the above-mentioned places. The eruption made its appearance the 29th of September, 1538, the feast of St. Michael the Angel; it was on a Sunday, about an hour in the night; and as I have been informed they began to see on that spot, between the hot-baths or sweating-rooms and Trepergule, flames of fire, which first made their appearance at the baths, and then extended to-

[n] So in each of these narratives, but the spelling authorized by the national Survey map is Pozzuoli.

wards Trepergule, and fixing in the little valley that lies between the Monte Barbaro and the hillock called del Pericolo (which was the road to the lake of Avernus and the baths), in a short time the fire increased to such a degree that it burst open the earth at this place, and threw up so great a quantity of ashes and pumice-stones mixed with water as covered the whole country; and in Naples a shower of these ashes and water fell great part of the night.

'The next morning, which was Monday and the last of the month, the poor inhabitants of Pozzuolo, struck with so horrible a sight, quitted their habitations covered with that muddy and black shower, which continued in that country the whole day, flying death, but with faces painted with its colours; some with their children in their arms, some with sacks full of their goods; others leading an ass loaded with their frightened family, towards Naples; others carrying quantities of birds that had fallen dead at the time the eruption began, others again with fish that they had found, and were to be met with in plenty upon the shore, the sea having been at that time considerably dried up. Don Pedro di Toledo, Viceroy of the kingdom, with many gentlemen, went to see so wonderful an appearance; I also, having met with the most honourable and incomparable gentleman, Signior Fabritio Moramaldo, on the road, went and saw the eruption and the many wonderful effects of it.

'The sea toward Baiæ had retired a considerable way, though from the quantity of ashes and broken pumice-stones thrown up by the eruption it appeared almost

totally dry. I saw likewise two springs in those lately-discovered ruins, one before the house that was the Queen's, of hot and salt water, the other of fresh and cold water, on the shore about 250 paces nearer to the eruption; some say that still nearer to the spot where the eruption happened, a stream of fresh water issued forth like a little river. Turning toward the place of the eruption, you saw mountains of smoke, part of which was very black and part was very white, rise up to a great height; and in the midst of the smoke, at times, deep-coloured flames burst forth with huge stones and ashes, and you heard a noise like the discharge of a number of great artillery. It appeared to me as if Typhœus and Enceladus [o] from Ischia and Ætna, with innumerable giants, or those from the Campi Phlegræi (which, according to the opinion of some, were situated in this neighbourhood), were come to wage war again with Jupiter. The natural historians may perhaps reasonably say that the wise poets meant no more by giants than exhalations shut up in the bowels of the earth, which not finding a free passage, open one by their own force and impulse and form mountains, as those which occasioned this eruption have been seen to do; and methought I saw those torrents of burning smoke that Pindar describes in an eruption of Ætna, now called Mon-Gibello in Sicily: in imitation of which, as some say, Virgil wrote the lines:—

> "Portus ab accessu ventorum immotus, et ingens
> Ipse, sed horrificis juxta tonat Ætna ruinis [p]," &c.

[o] 'Fama est,' &c.—Æn. iii. 578.

[p] Æn. iii. 570 et seq.

'After the stones and ashes with clouds of thick smoke had been sent up by the impulse of the fire and windy exhalation (as you see in a great cauldron that boils) into the middle region of the air, overcome by their own natural weight, when from distance the strength they had received from impulse was spent, rejected likewise by the cold and unfriendly region, you saw them fall thick, and by degrees the condensed smoke clear away, raining ashes with water and stones of different sizes according to the distance from the place; then by degrees with the same noise and smoke it threw out stones and ashes again, and so on by fits. This continued two days and nights, when the smoke and force of the fire began to abate. The fourth day, which was Thursday, at 22 o'clock, there was so great an eruption, that as I was in the gulf of Pozzuolo, coming from Ischia, and not far from Misenum, I saw in a short time many columns of smoke shoot up with the most terrible noise I ever heard, and bending over the sea came near our boat, which was four miles or more from the place of their birth; and the quantity of ashes, stones, and smoke seemed as if they would cover the whole earth and sea. Stones great and small, and ashes more or less, according to the impulse of the exhalations, began to fall, so that a great part of this country was covered with ashes; and many that have seen it say they reached the Vale of Diana, and some parts of Calabria, which are more than 150 miles from Pozzuolo.

'The Friday and Saturday nothing but a little smoke

appeared; so that many taking courage went upon the spot, and say that with the stones and ashes thrown up a mountain has been formed in that valley not less than three miles in circumference, and almost as high as the Monte Barbaro, which is near it, covering the Canettaria, the castle of Trepergule, all those buildings and the greater part of the baths that were about them; extending south towards the sea, north as far as the lake Avernus, west to the sudatory, and joining east to the foot of the Monte Barbaro; so that this place has changed its form and face in such a manner as not to be known again: a thing almost incredible to those who have not seen it, that in so short a time so considerable a mountain could have been formed. On its summit there is a mouth in the form of a cup, which may be a quarter of a mile in circumference, though some say it is as large as our market-place in Naples[q], from which there issues a constant smoke; and though I have only seen it at a distance, it appears very great.

'The Sunday following, which was the 6th of October, many people going to see this phænomenon, and some having ascended half the mountain, others more, about 22 o'clock there happened so great and horrid an eruption, with so great a smoke, that many of these people were stifled, some of which could never be found. I have been told that the number of the dead or lost amounted to twenty-four. I believe henceforward it

[q] At present the crater is much larger than either of these estimates. It is about a quarter of a mile in diameter, but longer in the direction from west to east.

VESUVIUS 1868

MONTE NUOVO 1868

will not have such force, though the eruption of the Sunday was accompanied with showers of ashes and water which fell at Naples, and were seen to extend as far as the mountain of Somma, called Vesuvius by the ancients; and as I have often remarked, the clouds of smoke moved in a direct line towards that mountain, as if these places had a correspondence and connection one with the other. In the night many beams and columns of fire were seen to proceed from this eruption, and some like flashes of lightning.

'We have then many circumstances for our observation; the earthquakes, the eruptions, the drying up of the sea, the quantity of dead fishes and birds, the birth of springs, the showers of ashes with water and without water, the innumerable trees in that whole country, as far as the Grotto of Lucullus, torn from their roots, thrown down, and covered with ashes, that it gave one pain to see them: and as all these effects were produced by the same cause that produces earthquakes, let us first enquire how earthquakes are produced, and from thence we may easily comprehend the cause of the abovementioned events.'

The other account of the formation of the Monte Nuovo, by Pietro Giacomo di Toledo, runs thus:—

'It is now two years that this province of Campagna has been afflicted with earthquakes, the country about Pozzuolo much more than any other parts; but the 27th and 28th of the month of September last, the earthquakes did not cease day or night, in the above-

mentioned city of Pozzuolo. That plain[1] which lies between the Lake of Averno, the Monte Barbaro, and the sea, was raised a little, and many cracks were made in it, from some of which issued water; and at the same time the sea, which was very near the plain, dried up about two hundred paces, so that the fish were left on the sand a prey to the inhabitants of Pozzuolo. At last, on the 29th of the said month, about two hours in the night, the earth opened near the lake, and discovered a horrid mouth, from which were vomited, furiously, smoke, fire, stones, and mud composed of ashes; making at the time of its opening, a noise like very loud thunder. The fire that issued from this mouth went towards the walls of the unfortunate city; the smoke was partly black and partly white; the black was darker than darkness itself, and the white was like the whitest cotton; these smokes rising in the air seemed as if they would touch the vault of heaven; the stones that followed were by the devouring flames converted to pumice, the size of which (of some I say) were much larger than an ox.

'The stones went about as high as a cross-bow can carry, and then fell down, sometimes on the edge, and sometimes into the mouth itself. It is very true that many of them in going up could not be seen, on account of the dark smoke; but when they returned from the smoky heat, they showed plainly where they had

[1] The Italian term Piano does not quite correspond in meaning to the English word 'plain': it is often applied to a surface which may be more or less undulated between or surrounding mountainous tracts.

been by their strong smell of fetid sulphur, just like stones that have been thrown out of a mortar, and have passed through the smoke of inflamed gunpowder. The mud was of the colour of ashes, and at first very liquid, then by degrees less so; and in such quantities that in less than twelve hours, with the help of the above-mentioned stones, a mountain was raised of a thousand paces in height[s]. Not only Pozzuolo and the neighbouring country was full of this mud, but the city of Naples also, the beauty of whose palaces was, in a great measure, spoiled by it. The ashes were carried as far as Calabria by the force of the winds, burning up in their passage the grass and high trees, many of which were borne down by the weight of them. An infinity of birds also, and numberless animals of various kinds, covered with this sulphurous mud, gave themselves up a prey to man.

'Now this eruption lasted two nights and two days without intermission, though, it is true, not always with the same force, but more or less: when it was at its greatest height, even at Naples you heard a noise or thundering like heavy artillery when two armies are engaged. Thè third day the eruption ceased, so that the mountain made its appearance uncovered, to the no small astonishment of every one who saw it. On this day, when I went up with many people to the top

[s] The meaning is 1,000 paces of *ascent*. The slope of Monte Nuovo, much exaggerated in the usual illustrations, is at a maximum 22°, except for small distances. In a straight line, the ascent from the sea is about one quarter of a mile.

of this mountain, I saw down into its mouth, which was a round concavity about a quarter of a mile in circumference [t], in the middle of which the stones that had fallen were boiling up, just as in a great cauldron of water that boils on the fire. The fourth day it began to throw up again, and the seventh much more, but still with less violence than on the first night. It was at this time that many people who were unfortunately on the mountain were either suddenly covered with ashes, smothered with smoke, or knocked down by stones, burnt by the flame, and left dead on the spot. The smoke continues to this day, and you often see in the night time fire in the midst of it. Finally, to complete the history of this new and unforeseen event, in many parts of the new-made mountain sulphur begins to be generated.'

It is often stated in notices of this great eruption that it contracted the area of the Lucrine Lake very sensibly: there is, however, no obvious proof of this, though it is not in the least improbable. That it rose out of that lake is plainly incorrect. In general we see in it a local outthrow of stony, ashy, and perhaps muddy materials, with very little change of the general features of the country: in the main a volcano of eruption.

Returning to Avernus, we perceive it to be encircled on all sides but the south; and round half the sweep of this surrounding crest, is another of twice its diameter, answering to Somma. A line drawn north and

[t] At present one quarter of a mile in diameter.

south through Avernus, cuts off this old crateral edge, as a line drawn west-north-west cuts off the old ridge of Somma. They are marks, probably, in each case, of a great change in the condition of the volcanic mountains; indices of a new order of phænomena, of which Monte Nuovo is the last yet observed. We have in fact here three volcanic periods marked as in a diagram: (1) the large old crater, now degraded and half destroyed, of the Monte Grillo, one mile across; (2) the Avernus, about five-eighths of a mile; and (3) the Monte Nuovo, about a quarter of a mile across.

If now we turn to examine the coast-line, we shall see at Misenum, at Baiæ, in the concave Island of Nisida, in the double sweep of hills above Naples, divided by the ridge of St. Elmo and Castello del Ovo, and about Pausilippo, evidence of old broken and degraded crateriform ridges, without lava-currents, very like in general meaning to the Phlegræan hills. Farther in the interior, Pianura in its circular plain, the larger sweep of the Piano di Quarto, (volcanic aggregates, like the rock called Piperno, and tufaceous strata, with marine imbedded shells at Pausilippo), combine with Monte Barbaro, Monte Cigliano, and other basins, to satisfy us that the whole Phlegræan land is the gift of volcanos originally bursting up from and through the sea-bed; which, extensively upraised in several places, is found to have been itself produced by sediments derived from volcanos probably of far earlier date than any traces even of the oldest now visible on the Italian soil.

Westward, or more exactly west-south-westward, of

the district we have been considering, rise the islands of Procida and Ischia, both composed of volcanic accumulations.

Again we recur to Strabo, in his fifth book of Geography, for a brief description of these islands and their early history:—

'In front of Misenum is Prochyta (Procida), once torn away from Pithecusa (Ischia). Pithecusa was inhabited by Eretrians and Chalcidians[u], in great prosperity, on account of the rich soil and the gold mines, but they left the island, terrified by earthquakes, and the outbursts of fire, sea and hot water. For to such occurrences is the island subject, and on this account a party of occupation sent by Hiero, Tyrant of Syracuse, abandoned their fortifications, and quitted the place. To them the Neapolitans succeeded.

'On these occurrences was founded the fable of Typhon, who is said to lie extended beneath the island, and to throw out fire and water, when he turns on his side, and sometimes even to throw up small islands containing hot water. More to be relied on is the saying of Pindar, starting from observation of the phænomena. For all the great sea tract, from Misenum to Sicily, is based on fire, and has in the deep parts cavities communicating with each other and with the main land. Wherefore it is that Ætna manifests itself to be of this nature, as all historians relate, and the Lipari Islands, and the country of Dicæarchia [Puteoli],

[u] The sentence is not clear as to the occupation by these races being contemporaneous.

Neapolis, Baiæ, and Pithecusa. Which Pindar contemplating declares that under the whole region Typhon lies :—

> "Beneath old Cuma's sea-girt hills oppressed,
> And mighty Ætna burning on his breast."

'Timæus says that of this island of Pithecusa, though many incredible things were handed down by tradition, it happened a little before his day, that the ridge of Epomeus, in the middle of the island, being shaken by earthquakes, threw up fire, and tossed into the sea the country on its seaward face, while the earthy mass rising in dust, and swept on by a whirlwind, returned to the island, and the sea, after retiring three furlongs, rolled in again and deluged the land, and extinguished the fire.'

This passage shows the main features of a great eruption—the earthquake, the violent explosion, the clouds of ashes, the agitation of the sea—but no lava is mentioned. Taken in connection with the criticism on Pindar quoted above, it must appear to any one versed in volcanic phænomena, conclusive in favour of the extent and exactness of early Greek observation and reasoning on these uncommon occurrences. Strabo is certainly the greatest of all the ancient Plutonists.

Ischia—Pithecusa—Ænaria—Inarime, for it is entitled to either of these names [x], boasts a high central moun-

[x] Inarime in Virgil; Pithecusa in Strabo; Ænaria in Pliny; Ischia is modern. Inarime has been thought to have been derived from the Homeric εἰν Ἀρίμοις, under which Typhon was laid, but it is said that Arimi in Etruscan signifies Apes, and Pithecusa means abounding in

tain which has erupted in historic times, viz. 91 years B.C. (170 years before the first recorded eruption of Vesuvius), and again in the year A.D. 1302. The volcanic summit is called Epomeo, a grand mountain 2,605 feet high, composed of trachyte and pumiceous tufa, without a crater at the top, but with one largely excavated side, and several lateral outbursts, as the Monte Rotaro and Monte Campignano.

Dr. Daubeny, who examined Ischia with great care, thus collects its volcanic history :—

'Ischia appears to have been subjected to volcanic action of as many different periods as the neighbourhood of Naples itself; its pumiceous conglomerate corresponding with the Pozzolana, its trachytes to the rock of the Solfatara, and the lava of the Capo d' Arso (which flowed from Monte Rotondo) to those of Vesuvius. Even the ancients were fully aware of its volcanic nature, attributing it to the giant Typhœus being confined under the mountain; and Strabo relates that a colony sent over by Hiero, Tyrant of Syracuse, was so alarmed by the frequent earthquakes that they deserted the island.

'Not less was the consternation excited by the eruption which gave rise to the lava-stream of Arso already noticed. Thus Villani, in his "Florentine History [y]" observes, that in the year 1302 a tremendous

Apes. Can this indicate a tradition of pre-historic times? Pliny says the name Pithecusa was given on account of the potteries (πίθος) in the island. Nat. Hist. iii. 6.

[y] Lib. viii. c. 53.

conflagration broke out from this crater, so that through the whole extent of the island much of the country was consumed and laid waste, and even many of the people and of the cattle in it were destroyed. Multitudes also, to escape from the danger, fled to Procida, Capri, and the main land, and remained there during the continuance of the internal commotions, which lasted more than two months.

'At present the only indications of volcanic action are those afforded by the hot springs so common throughout the island.'

Dr. Daubeny, from whose great work on Volcanos these passages are extracted, examined most of these springs, the hottest of which, at Gurgitello, near Casamicciola, has a temperature of 142°. None of them yield any gas; no ammoniacal salts are deposited by them; nor in the frequent exhalations of hot air from fissures in the Ischian rocks is any difference observed from common air as to the proportions of oxygen and nitrogen.

If we consider on a map of Italy the situations of the most distinguished points in the several volcanic systems of Rome, Naples, and Sicily, their relation to the line of sea-coast and the ridges of the Apennine mountains is easily traced.

The relation of these volcanos to the actual or ancient sea-coast is double; the sea perhaps feeds the volcano with water; the coast levels have been determined by volcanic movements. But there is an equally obvious though quite opposite relation between the sites of the volcanos and the ridges of ancient strata—

mesozoic and palæozoic—in the Apennines. For in the midst of these ranges, great and violent as have been the movements to which they have been subjected, there are hardly any traces of truly volcanic eruptions. The great old volcano of Mount Vultur, east of Vesuvius 80 miles, is an apparent exception, for it is situated among the ridges of Apennine limestone. But then it is near the crossing of these ridges, as may be seen on the map, at a point of weakness, in a situation of easy opening from below to the surface. In the other cases it is readily seen that all have opened in what was once the sea, an extended part of the Mediterranean. This is even the case in the Euganean hills and other volcanic vents in North Italy, as well as in Albano, and the Ciminian hills, far as they are now from the sea.

There is, however, another aspect to this question, which seems to connect the exhibition of volcanic energy—such as we know it—with *geological time*. For as it is not found, by searching the mesozoic and earlier strata of the Apennines, that any truly volcanic rocks appear amongst them; so is it rarely that any plutonic rocks among them indicate local igneous excitement *during the formation* of any of them. All the volcanos of South Italy are of later, i. e. of cænozoic date. In North Italy the same result is found. The volcanic action of the Euganean and the Vicentine hills—extensive and varied—was all of later date than any of the mesozoic rocks of the Alps. This late date of volcanic action is very frequently observed in other parts of Europe: it is found again

in other parts of the world, and may fairly be called general, in the popular sense of comprehending a large part of the known cases or examples.

That it is not indeed a universal occurrence, the three toadstones of Derbyshire, interpolated in the mountain limestone and traversed by mineral veins, the basaltic cap rocks of the Clee hills, and the flow of greenstone between the coal strata near Charnwood Forest, plainly prove; for these rocks are of volcanic nature, though perhaps not all connected with sub-aërial or even sub-aqueous eruptions.

The extinct—long since extinct—volcanos of Auvergne, the Eifel, the Rheinthal, the Vicentine and the Euganean hills, at whatever epoch they *ceased* to be active, certainly manifested themselves very largely in *early* cænozoic periods; those of Central and Southern Italy seem not to have started so soon, and among these the Ciminian, and Albanian, and Vulturian craters were extinguished in a remote age, while the Phlegræan area was on the whole dying out, and the fires of Vesuvius and Ætna were blazing in the fierceness of youth.

Thus three relations of volcanic energy are assignable to geographical conditions: first, it is not in high mountain-chains, however great the disturbances in them, that volcanic energy is specially seated; next, that it is in the sea or near the coast now, and that it was near the sea or great inland waters in earlier times, that volcanos burst forth; thirdly, that the area of activity in Europe has been on the whole shifted southward during the course of geological time.

Taking these three inferences in the order set down, we observe that great mountain movements, by which changes of vast extent have been made in restoring the terrestrial equilibrium, are by this very condition to be regarded as bringing to rest some primary state of extensive disturbance. In whatever length of time they were raised, this rise was of the nature of a convulsion or struggle of contending forces. The movement accomplished, the struggle was ended; a new condition of land and sea; a new series of changes to be met by a crisis at some future time. No volcanic excitement was to be expected from such an event as the uprising of even a mountain-chain on the line of the elevation.

Next, it must be observed that the rising of one portion of the earth's surface is compensated by de-

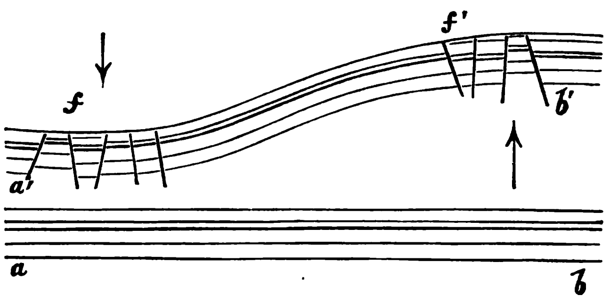


Diagram XXX.

pression, at least relative depression, of another. This will be evident by considering a simple diagram such as No. XXX, where *a b*, horizontal strata, are subjected to

general upward pressure, growing greater at b; and a' b' the same strata, raised at b' and sunk or less raised at a'. It is conceivable that the whole movement may be represented in a different way, viz. as the effect of 'end pressure,' and in this case, as well as in the former, the effect would undoubtedly be the rising of one part and the real or relative sinking of another: the comparative extent of rising and sinking being determined by the local conditions. Whether the rise and fall were sudden or gradual, there is no reason to doubt that the strata would be fissured and displaced, as at f and f': and if after the depression a' were below the sea, and after elevation b' were above it, then the fissures at a' would admit of a communication of sea-water to the subjacent mass of the globe, but at b' only air, or very small supplies of rain.

Now, abundance of water, having access to the hot interior of the earth, is an element, not of continental elevation and marine depression, but of *volcanic excitement;* and thus we may perceive how much of truth is in both forms of geological speculation which are so strongly contrasted by their respective adherents—'Erhebungs-Cratere' and 'Cones of Eruption.'

Lastly, in harmony with these results, volcanos have ceased to be active in tracts of country which by general elevation have rejected the sea, and to a certain degree this is an effect which happened earlier in the north than in the south of Europe; earlier in countries north of the Alps than in those south of that lofty range. The basins of Bordeaux and Paris, of the Danubian

valley and the Rheinthal, had been deserted by the northern sea; while yet the Mediterranean filled the valley of the Po, and washed the foot of the Apennine and Sicilian limestones.

In the whole course of the natural history of Italy, since its day of empire, previous to its republican rise, and through a still longer time before men dwelt in Campania, the land has been subject to rises and depressions, the former most clear, certain, and numerous, the latter also real but less extensive and less evident. To take the phænomena in the reverse order of time, beginning with the most recent, will be most satisfactory and most instructive.

Very near to the sea-shore, in the western part of Pozzuoli, the traveller is conducted to a square marble area, somewhat depressed below the general level of the ground and house-foundations, surrounded by many (forty-two I believe) smaller apartments. Four flights of steps led downward to this broad floor. On it stood many columns, some of granite, some of Cipolino (calcareous and lined with green serpentine), some of Rosso Antico, and others of African (brecciated) marble. In the centre is a circular portion, like the cella of a temple, round which stood many (eighteen) columns of Rosso Antico, now removed to Caserta. Still standing erect are three tall columns of Cipolino marble—which as being calcareous with magnesian veins may be called Ophicalcite—brought, it is believed, from Egypt. This building was dug out and cleared from the mass of earthy accumulations which filled it, and

it was then found that the great pillars of Cipolino marble were incrusted at two levels by still adherent matter, and for a space of 7 or 8 feet (above these incrustations) were perforated by boring-shells, well known to be living in the Mediterranean Sea,—the Mytilus lithophagus of Linnæus, now called Lithodomus. The level of the marble floor is such that, as we were informed, 'in winter it is entirely covered by water; in the summer time not so.' The difference is ascribed to the winds which 'push up' the sea in stormy weather. By the marks which were shown to us this difference amounts—probably in extreme—to 30 inches. Mr. Mallet found a difference of 25 inches to be occasioned by a gale of wind of some persistence.

What is the interpretation of these facts? in particular how were the columns penetrated by the marine bivalves? When first discovered in the last century (A.D. 1750) the prevalent opinion was in favour of its being a temple dedicated to Serapis; some argument for its being a temple being founded on the magnificence of the court (70 feet square) and the height and splendour of the columns—forty-six in number originally. But there was no special ground for thinking it dedicated to Jupiter Serapis. Far more probable is the later view of its being a great bathing establishment of the highest class, situated by a thermal spring, and near to the sea. It is, however, convenient to call it by the popular title. The sea-water now enters and returns from the temple area, by soaking through the porous substances, which, partly covered by houses, the street and a wall,

occupy about 100 feet in breadth. To complete this statement, it must be added that at a depth of 5 feet below the present floor, there is another, formed of mosaic work, after the manner of those now so conspicuous in the vast baths of Caracalla at Rome.

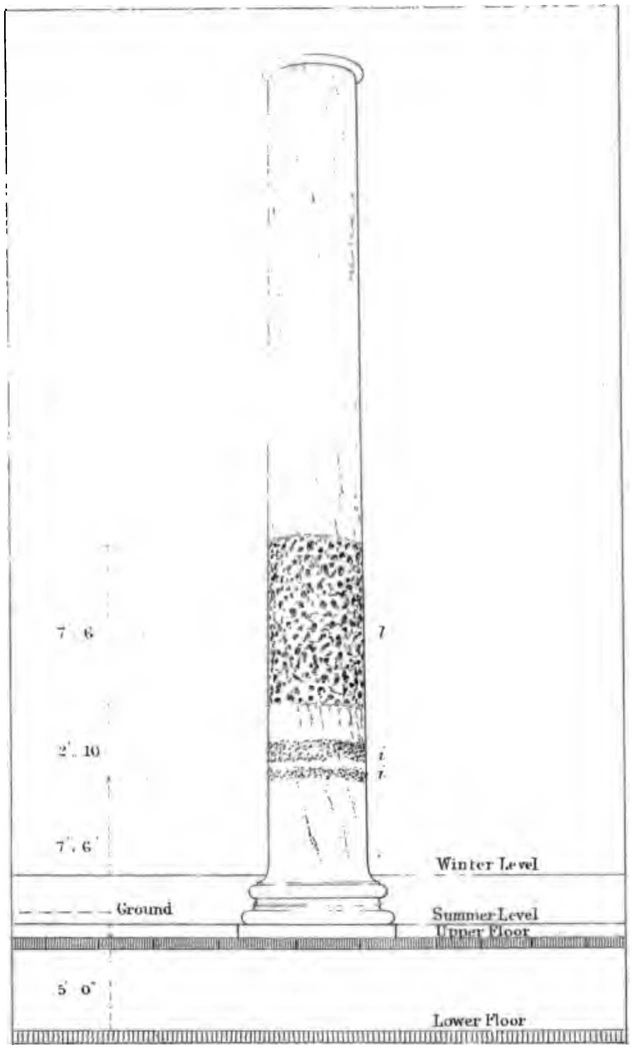
It is obvious that the marble columns have been exposed to the sea and boring-shells, to a height of 16 or 18 feet above the base of the shaft—for to this height the perforations extend. The shaft of the column is 42 feet high[1]: the base of the column measures 2 feet 6 inches, and the floor on which it rests may be regarded as about 1 foot or 1 foot 3 inches below the mean high-water level of the Mediterranean. The upper limit of the bored surface of the column is about 16 feet above this level: 7 or 8 feet of the surface below are occupied by the borings, and about 7 or 8 feet of the shaft (7 feet 6 inches) below them are clear of borings, but marked by two bands of adherent incrustation.

The first suggestion to every mind is that the columns were penetrated by the sea-shells, while they with all the space around were at a lower level than now; and that the temple and town and sea-shore have all been raised since that time to their actual height.

The marble floor must have been at one time under the sea-level about 17 feet 6 inches; it is inconceivable

[1] This is the usual statement. By an observation with our clinometer the height seemed greater. The other measures may be in error a few inches, where they differ from the data ascertained with so much care by Mr. Babbage.

Plate 7.



J.P. & J.F.L.

J.W.L.

that the depression could have been originally intended; most probably the floor was laid at no great difference of level from the sea—it might have been laid nearly at the level which it now occupies, for then by proper means the sea-water might be admitted and returned, and the baths kept in good state. If so the history of the place is thus—

Epoch 1. Bath floor nearly at the sea-level.
Period 2. Depression of the whole region.
Period 3. Re-elevation of the whole area.
Epoch 4. Bath floor again nearly at the sea-level.

This is the view now generally adopted. But there are other opinions. The postulates on which it rests are two—first, that the sea-shells made their holes and dwellings at or near the sea-level; secondly, that the temple-floor was laid at or near the sea-level. In opposition to the first, Goethe, and after him Daubeny, advocated the possibility of a limited sea-basin being formed at a level as much at least above the general sea-level as the highest line of the mollusks; this peculiar sea-pond being effected during the volcanic disturbances of the region. In fact a raised lagoon, which, being drained, left marks of its old level. This hypothesis had no longer duration than till Professor Forbes and Mr. Babbage, by examination of the neighbouring coasts, showed that a real upward movement had happened all about the area of the temple, and for considerable spaces both northward and southward. Dr. Daubeny abandoned this explanation in the second

edition of his work. Against the second postulate it has been suggested by Mr. Mallet that the use of the building for a bath might justify the opinion that it was originally built very much below the general level of the surface, perhaps in a natural hollow; so as to admit the sea to enter and remain at a considerable depth—making perhaps a large public plunging-bath, with separate smaller bathing-rooms around. The present appearance he ascribes without hesitation to elevation of the temple and surrounding tract. Depression after the first construction he deems an unnecessary incumbrance to the general theory.

If the measures already given can be relied on, the temple-floor must have been laid, on Mr. Mallet's hypothesis, at least 12 or 16 feet lower than the sea-level, a thing hardly conceivable, even in the peculiar volcanic soil of Pozzuoli, and the less probable because of the mosaic floor which is found to extend over the same area, 5 feet below the marble floor. Nor is it easy to imagine any way of emptying such a bath so much below the sea-level; though Mr. Mallet suggests the porous and absorbent nature of the soil surrounding and subjacent to the bath. 'The dry and porous subsoil, consisting of 12 to 20 feet of tufa, lapilli, and scoriæ, would soak away any amount of water, if simply discharged into a pit sunk in it, below the level of the baths; a method of drainage actually practised from a remote age to the present day[a].' Mr. Mallet attributes

[a] Neapolitan Earthquake, vol. i. p. 221.

to a slow process of landslip—through removal of materials by sea-action—a certain inclination of the columns and the slope of the floor, both toward the sea, which he has observed.

Upon the whole it seems the safest opinion that the land about the temple has been both depressed and raised, depressed it is probable twice, since the upper marble floor must be supposed to have been laid at its level, in consequence of the failure of the earlier mosaic to meet the requirements of the case. One elevation at least must be admitted, and there may have been more than one. The whole of the movement upward and downward, including even the first depression, must probably be admitted to have happened since the days of Strabo, by whom the bathing establishments at Baiæ are mentioned as much exceeding those of Neapolis, but Puteoli is not thus praised. The style and grandeur of this temple, or bathing edifice, also claim for it a date as late as the Imperial times; and thus within 1600 or 1800 years we have to admit something like 16 feet downward and as much or more [b] upward movement, with no marked evidence that it was the effect of earthquake. Nor has any known earthquake, of the many that have occurred, been proved to have produced anything like so great an effect.

Yet there appears good evidence in favour of the opinion that earth-movements, if not of the convulsive

[b] Lyell requires 23 feet of elevation. Bk. II. cap. xvi.

kind we call earthquakes, did really perform this work, and within the time specified. This evidence, collected by Breislak [c], Mr. Babbage [d], and Professor Forbes [e], to whose admirable memoirs reference must be made for particulars, has been brought into a clear light by Sir C. Lyell in the part of his great work already quoted.

Breislak ascertained that in the atrium of the temple, inscriptions were found which recorded the adornment of the interior with precious marbles, by Septimius Severus and Marcus Aurelius, early in the third century. It must then have been in its original, or else in its second stage—perhaps we may adopt the latter view—there may have been a depression of 5 feet, a new floor, restoration, and adornment. Nothing is absolutely known of any further change of level till the early part of the sixteenth century. An Italian author, first quoted by Forbes, named Loffredo, writing in the latter part of that century, states that fifty years before his date the sea washed the base of the hills west of Pozzuoli, where now is the rather broad tract of land, about 20 feet above the sea, called La Starza. A person might have fished from the ruins called the Stadium, at the edge of that now inland cliff. He wrote in A.D. 1580—therefore in A.D. 1530, the region in question was really lower than it is at present, and the temple had sunk with it. The only great

[c] Voy. dans la Campanie, ii. p. 167.
[d] Proceed. of Geol. Soc., No. 36, March, 1834.
[e] Ed. Jour. of Science, New Series, ii. 281.

disturbances to which we can refer this depression, are the eruption of the Solfatara in A.D. 1198, and an earthquake very injurious to Pozzuoli in A.D. 1488; but there may have been other events as important which are not on record.

In the early part of the sixteenth century, the land began to rise above the water, and documents are preserved by which Ferdinand and Isabella, in A.D. 1503 and 1511, granted to the City and University of Pozzuoli a certain territory where the sea was drying up (A.D. 1503), or was dried (A.D. 1511).

But the main elevation, according to the clear testimony of Loffredo, was not completed till somewhat later than A.D. 1530. The great convulsion which accompanied the birth of Monte Nuovo happened in A.D. 1538, and it is upon record that then the sea-shore was dried up about Pozzuoli and Baiæ, showing among other things 'newly discovered ruins.'

According to a recent measure by Professor Guiscardi, the level of land and sea in the Gulf of Pozzuoli is not in a state of permanent rest, but is still undergoing change, and the land is sinking. By a mark set on the so-called Mole of Caligula, at 9 a.m. on the 12th of June, 1840, the level of the water, in a calm day, and under favourable circumstances, was found at the same hour on the 9th of June, 1865, after a quarter of a century, to stand 0·349 metres higher than on the first occasion,—in a century this would amount to 1·396 metres. What wind there was came from the E.N.E., which would rather tend to

lower the water, so that the result stated may be a trifle less than the truth[f].

[f] How often, in reasonings on the variability of the relative level of land and sea, must we regret the limited views of experimental science! We determine by accurate processes of trigonometry, or by exact levelling, the height of an interesting point of mountain to be 2400 or 2400 + *d* feet 'above the sea,' but we rarely leave permanent marks of the 'mean tide level.' If we leave such a mark, as occurred to De la Beche, myself, and some other members of the Geological Survey at Tenby in 1841, what use is made of it? If we have levelled, at a cost of 500*l.* or so, the whole line from the Bristol Channel to the English Channel, and recorded this admirable work of Mr. Bunt and the British Association, when will another accurate hand be set to re-examine the line and see if our own island be not rising or falling like Delos? Why not take advantage of the next great meeting in South Devon, and try what has been the temper of Nature during the last *thirty* years? Mr. Mallet may be invited to turn his attention to this problem.

CHAPTER IX.

VOLCANIC ENERGY.

'Tot locis tot incendiis rerum natura terras cremat.'
PLIN. *Hist. Nat.* ii. 106.

In considering the history of Vesuvius as of other volcanos,—as indeed of other natural phænomena,—we distinguish not only *periods* of greater and less action, but *crises* of violence and epochs of unusual energy. In the series of eruptions from Vesuvius, we may fix on those of A.D. 79, 1631, 1737, 1767, 1779, 1794, 1822, 1855, 1858, as among the more remarkable for the extent of the lava-currents, or the abundance of ashes, or the height and splendour of the eruptive columns, which often seemed to deserve the title of liquid fire spouted up to the clouds.

The magnitude of eruptions may be in some degree estimated by the mass of lava ejected. Thus in A.D. 1737, the mass of lava was estimated at 10,237,096 cubic metres, and in A.D. 1794 a larger quantity flowed, estimated at 20,744,445 cubic metres, both calculations being made by Breislak. This last estimate would give

ten inches in depth over the whole surface of Paris. On this and other occasions vast quantities of ashes were ejected, which fell over an area much exceeding the whole surface of Vesuvius and Somma. If we take this area at 100 square miles (certainly much below that really covered by ashes in A.D. 79), and allow an average depth of three inches, the quantity of ashes would appear to have been nearly as great as the greatest known flow of lava. But over Ottajano, and Pompeii, and Stabiæ; over Herculaneum and Resina; and even over Misenum and Capri, the ashy-shower has been several palms, feet, yards, and even fathoms in depth. Judging from many sections, we may firmly believe the ashy showers to have carried three times as much matter from Vesuvius as the lava-currents.

The cone of Vesuvius, consisting of ashes and lava-streams, has been many times formed, and destroyed, and renewed within the crescent of Somma. If we take as an average of this cone, two miles for the diameter, and one-third of a mile for the height, its cubic content will be 0·339, or about one-third of a cubic mile. The great mass of lava which was measured by Breislak (A.D. 1794), amounts to $\frac{1}{200}$ of a cubic mile, or about $\frac{1}{64}$ part of the assumed average cone of Vesuvius. Sixteen such eruptions would remove in lava and ashes a mass of matter equal to that of Vesuvius; and we may fairly allow that at least so much has been removed by the eruptions of A.D. 1631 and subsequent years. This judgment may be firmly supported on the evidence yet remaining of the lava-currents. If we admit, as

surely we may, the effect of the great convulsion of A.D. 79, and the 1,552 years which intervened between it and its great imitator in A.D. 1631, to have been equal to what has happened since, we have a second mass equal to Vesuvius; and finally, as these computations take no account of the vast body of fine dust which drifted hundreds of miles away, we may add a third volume equal to either of the others. Upon the whole there can be little reason for hesitation in accepting as probable the opinion of Seneca, that the ancient Vesuvius (including Somma) had thrown out much more than its own bulk; and we may confidently add to this the statement that since the days of Seneca,—in the course of 1,800 years,—the modern Vesuvius has repeated the process, and ejected of lava and ashes thrice its own bulk.'

The cubic content of such a mass as that of the whole mountain of Somma as once it appeared in its complete state, above the level of the sea, may be thus computed. Taking the base at ten miles across, and the height equal to one mile and a quarter, we have $10^2 \times \cdot 7854 \times \frac{5}{12} = 32\cdot 75$ cubic miles. But not all this mass was erupted into air: if we take the lower fifth of the whole height for tufa accumulated under water and afterwards broken up and raised, the subaërial ejections will amount to sixteen cubic miles of matter, and the time occupied in the formation of Somma cannot be computed at less than 288 centuries; but must in fact be supposed far greater; because during the eruptions ashes must have been scattered far

and wide, over Southern Italy and the Mediterranean Sea; and because, as in modern Vesuvius, there must have been removals and replacements of cones, craters, and slopes, not once but often, and this is not allowed for in the calculation.

If we endeavour to picture to ourselves the probable condition of the earth below the ancient summit of Somma, we must first arrange in a given depth, without symmetry, a system of cavities and fissures equal in cubic space to the mass of the mountain above the sea; the fissures being of the usual order in rocky masses, and variously connecting the different cavities. Let the depth be taken at ten miles; in this case the fissures must have a space area in mid-section equal to four miles. Fissures, as commonly seen in rocks which have undergone violent displacement in old geological times, are from 0 to 5, 10, 20, and more feet across, are distant from one another a few feet or a few yards, and open sometimes into pockets or cavities of larger area. Assuming only one yard of average breadth for the fissures and cavities under Somma, and twenty-five yards for the average distance in each horizontal mile, the result will be a cavernous space under Somma equal to its bulk above the sea when complete.

In Diagram XXXI the fissures are arranged according to the probable hypothesis derivable from the study of much dislocated rocks. No one vast cavity is supposed to remain under the mountain ready to receive it in the arms of the fire out of which it sprang, but a broken mass of solid rocks readjusted in confusion

by many earth-shakings in the course of prehistoric time:—

'rudera longinqui sensim præterlapsi ævi.'

It will readily occur to attentive inspection that a condition of fissured rocks is consistent with the occurrence of one channel to the surface more open

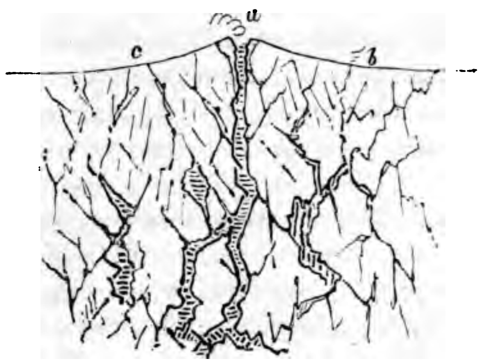


Diagram XXXI. FISSURES IN ROCKS UNDER VESUVIUS, to the depth of ten miles. (*Original.*) *a*. The crateral summit. *b*. Place of lateral discharge. *c*. Fissures reaching to the surface.

than others (as *a*); it is also with the occasional closing of that and the opening of another channel (as *b* or *c*): and that thus intermissions and changes of the place of eruption may easily be understood. Easily also may it be understood that the channels to the surface may become wholly closed in a given region, and all volcanic excitement there be laid asleep for centuries or thousands of years. Whether such repose can happen universally

in the earth as it seems to us to have happened in the moon, or this rest in one district must be compensated by extra activity in another, we cannot affirm or deny until the cause of the excitement is clearly apprehended. To this therefore we now proceed.

Several orders of phænomena which are observed before, during, and after eruptions of Vesuvius, conduct us to a satisfactory view of some of the characteristic mechanical and chemical actions which are connected with the subterranean disturbance, each being in some sort both an effect of preceding causes, and a cause of subsequent effects—a character of all natural agencies.

The land is much shaken, and even permanently fissured and displaced.

The sea is rejected from the shore, to return in mighty waves; or its bed is raised, and laid dry.

The sky is filled by uprushing volumes of expanded vapour, which speedily condense into cumulated clouds, and sometimes yield abundant rains.

Enormous columns of ashes rise with the vapour some thousands of feet, and are carried away by the winds over distant regions. Jets of solid stones, melted lava, and scoriæ are thrown up with violence to the height of 1,000 or 2,000 feet; either vertically, in which case they fall again into the crater, or at an angle inclined to the vertical, when they describe parabolic curves, and fall at distances of six or eight miles.

Currents of melted rock rise to the summit of the mountain, and flow over the crateral edge, or burst forth

from some fissure on the side or base of the cone,—the specific gravity of this lava being from two to three times that of water when solid, and two and a-half to three times that of water when liquid.

These are the mechanical phænomena, by the right interpretation of which we may hope to arrive at a knowledge of the *mass-forces* concerned, and specially to obtain an estimate or measure of their energy. The chemical effects—the constitution of the lava and ashes; the evolution of steam; the sublimation of metals, metalloids, and metallides; the outpouring of hydrochloric, carbonic, and sulphuric acids and salts in which they are constituents, must be appealed to for a knowledge of the nature and condition of subterranean matter, and of the *molecular* actions which accompany and to some extent share in the effects of the *mass-forces*, which we must first proceed to consider.

The movements of land and sea to which we give the name of earthquake are, as this name implies, accompanied by, or rather consist of, so far as our perception of them goes, undulations in the water, and vibrations in the land,—suddenly excited and rapidly passing on, so as to be described as 'shocks.' The water undulates, the land vibrates, under the influence of some subterranean 'stroke.' Whether this be occasioned by collision between solids, or between a solid and a liquid, or by rupture of a solid mass through accumulated pressure, may be matter of further enquiry.

An ingenious hypothesis on the subject of earthquake movement was proposed in the last century by the Rev.

John Mitchell, a Fellow of Queens' College, Cambridge, who was also distinguished for his researches in magnetism and his knowledge of geology. Mitchell conceived of the earth as composed of a solid crust and a fluid interior; and explained the earth-shake as a forced flexure of the solid crust over undulations excited in the subjacent fluid—much as a flexible cloth can be made to exhibit a rolling undulation over air set in motion below it. The origin of the disturbance need not now be considered. A piece of carpet held up at one end, the other resting on the ground and shaken, will show the effect very well.

The undulations supposed to be thus produced in the crust of the earth, are regarded as waves of translation, like tides in the open sea, moving in given directions from a centre or axis of disturbance, accompanied by tremors or vibrations in the rocks. The earthquake waves which they are intended to represent or explain are very broad; move with considerable and equal or nearly equal velocity; and occasion upward, downward, and lateral displacement according to the situation of the point with reference to the origin of the motion, and to local circumstances in the solid crust itself. In these particulars the hypothesis seems to agree in general with the facts observed.

This view of the undulations of an internal fluid influencing the flexible crust of the globe, has been fully adopted in modern times by the late H. D. Rogers, Professor of Geology at Glasgow, and his brother, Professor W. B. Rogers, of Virginia, whose experience in

North America made him well acquainted with earthquake phænomena. They are not only convinced of the general truth of Mitchell's theory, but further venture to apply it, not only to small tremors, but also to the permanent disturbances, such as anticlinals and synclinals, in the earth's crust [a].

Thus the modern transitory earthquake is regarded as a phænomenon of the very same order as the permanent flexure of the ancient strata, though on a reduced scale.

The application of this hypothesis of earthquake movement to the ground upward and downward is not now accepted by geologists; yet it must not be thought for that reason that the hypothesis itself is wrong in assuming the generation of waves in a subterranean liquid—if such exists—on the application of adequate force. And such waves would propagate themselves under a solid crust in the manner supposed, but would speedily die out.

It is not, however, to waves generated in such an interior sea of liquid rock that we must ascribe the earthquake; on the contrary, it is to the shock which makes the earth quake that we may better refer the possible wave of liquid beneath it.

No gradually accumulated pressure, no gradual diminution of pressure, would make such waves in the interior fluid until in one or the other case the excess or defect of pressure were relieved by a sudden or very

[a] British Association Reports.

rapid change of conditions. If such pressure, or want of pressure, were to reach a maximum, and the crust were to break on a given line, or about a given centre, one effect might be the generation of such a wave, no doubt; but in this case what is the use of the hypothesis?

Such a fracture would necessarily produce in the solid crust itself such waves of sensible movement as earthquakes manifest, and in such order and proportion as the phænomena indicate; while the undulations of a subjacent fluid, however real, could not exhibit effects so varying with distance from the origin, and local peculiarity in the regions under tremor, as to represent truly the facts known by observation. Moreover, the solid crust of the earth is not very flexible, and only partially continuous, and must surely be as much as ten miles in depth,—it is found by mathematical investigation of the astronomical phænomena of precession and nutation to be as a general rule very much thicker, —and it is inconceivable that it could be made to *bend* upwards and downwards as a mass, with the suddenness of earthquake shocks.

The most important bearing of earthquakes on the theory of volcanos is the means they afford of determining for both the depth or limits of the depth of their origin. Once begun in or near a volcanic centre, earthquakes propagate themselves according to the conditions of the rocky framework of the earth: and by study of their propagation, the rate of their movement, the force and direction with which the wave

rising from some depth reaches and strikes the surface,—these circumstances accurately observed at several points will determine pretty exactly the situation and depth of the shock, whatever it was, which caused the earthquake. To such a depth, at least, the solidity of the earth extends in the regions disturbed.

The mechanism of earthquake movement has been investigated by competent hands. The late eminent mathematician, Mr. Hopkins, of Cambridge, explained these tremors in the solid earth by the general theory of vibratory motion; and showed the existence of two orders of vibration; one accompanied by condensation and rarefaction of the original *volume*, and characterized by longitudinal vibration; the other marked by deviations from and efforts to recover the original unconstrained *form*, and characterized by transverse vibration. These two distinct but coexistent vibrations proceed in their course from a centre of disturbance with very unequal velocities, the longitudinal or normal vibration being the most rapid[b].

To determine the geographical centre of disturbance in an earthquake. See Diagram XXXII, p. 259.

If P and P' be two points in a horizontal plane surface, $H\,h\,x$, where the directions of the normal vibrations have been determined by observation to be in the lines PC and $P'C$; the place where these lines meet is the centre of disturbance at the surface, and is directly over O, the subterranean point where the disturbance originated.

The wave-crests or lines of contemporaneous disturbance are marked W and W'.

[b] On the Theories of Elevation and Earthquakes. Reports of British Association, 1847, p. 78.

By employment of other ingenious methods, devised by Professor Haughton and himself, Mr. Mallet was able to assign the centre of the great Neapolitan earthquake of A.D. 1857[c]. Not that it was specially Neapolitan or Vesuvian, for it shook a great part of Italy, and had its focus of energy at a considerable distance from Vesuvius, to the south-east, not in a volcanic region, but under the Apennine limestone.

The depth at which the disturbance began—'focus of earthquake-shock' as it may be termed—has also been well determined by Mr. Mallet for the earthquake already named, and by Schmidt and others for some other earthquakes.

If in a vertical surface, Hhy, at a point P, whose distance from C is known, θ the angle of emergence of the wave W—formed between its direction and the vertical PQ—be known, the line CO, equal to the depth of the focus, is determined; for CO = co-tangent of the angle θ on the radius CP.

Or if the velocity, v, of the wave-transit at P, at a given distance from C, be known, and also the velocity, V, of the wave proceeding normally from O—the depth CO is determined. For in this case p being taken at an indefinitely small distance from P, and PS a line drawn perpendicularly from OP, while the surface wave-motion, v, is represented by the space from P to p, its actual normal motion, V, is from S to p.

And $\frac{V}{v} = \frac{Sp}{Pp} = \sin\theta$, and if $CP = a$, $CO = a\cot\theta$,

$$= a\frac{\sqrt{v^2 - V^2}}{V}.$$

For methods of determining experimentally the angle of emergence θ, and the horizontal velocity v, reference may be made to the excellent authors already named.

[c] First Principles of Observational Seismology, 2 Vols. 8vo, 1862.

The determination of the value of V, the normal velocity, is also to be made by experiment, and has indeed been

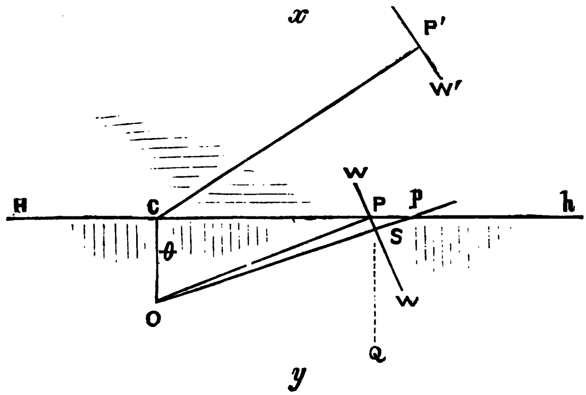


Diagram XXXII. Origin of Earthquake.

settled for some sorts of rock and some kinds of loose materials by Mr. Mallet and others. It may also be ascertained independently in any given earthquake region, by determining the horizontal velocities at three stations in the same straight line from *C*; or if the wave be spherical in front (not a common case), in any direction from *C*. The calculations are, however, a little troublesome. By any of these methods the depth *CO* becomes known; not indeed very accurately, but approximately. Mr. Mallet by employing twenty-six results of the emergent angle, in the earthquake of A.D. 1857, at various distances from the centre, obtained the following as very probable results.

Twenty-three started from the seismic vertical, at

depths varying from $2\frac{3}{4}$ geographical miles (16,705 feet), to $8\frac{1}{8}$ geographical miles (49,359 feet), the mean of these being above $7\frac{1}{8}$ geographical miles = 43,284 feet.

Eighteen of them started from the seismic vertical at depths whose average was $5\frac{3}{4}$ geographical miles (34,930 feet); the extremes differing only 12,000 feet.

The conclusions of Mr. Mallet were that the focal area, or cavity, or fissure, where the disturbance originated, having a mean depth of about $5\frac{3}{4}$ geographical miles, could not extend upwards and downwards above 3 geographical miles (18,225 feet); while by considering the directions of the wave at the surface, and the measure of the disturbing forces manifested there, it appeared that this focal space or fissure stretched through about 9 geographical miles in length. Here then, at this moderate depth, sprang into action the motive power of the earthquake; a sudden violent effort like a direct blow, rupture by tension, or elastic expansion of steam, the last-named agency being, in Mr. Mallet's opinion, the most probable.

The extreme depth of earthquake origin in the region of Naples was found to be little more than 8 miles (49,359 feet); is that the extreme depth from which the volcano draws its liquid sustenance? If it be so, then, as Mr. Mallet shows, the temperature at the volcanic focus, if derived from the general heat of the globe augmenting with depth, would be 883·6 Fahr. quite inadequate to maintain lava in fusion. The real temperature of flowing lava is found by a few observations to be about 2000°; and Mr. Mallet in his personal

inspection of the crater of Vesuvius, while lava was fluid in it, estimated that to be the temperature of its bright red mass, from which dry transparent superheated steam was ejected. Mr. Scrope admits a higher degree of heat.

Has the heat then a different origin; or is it unnecessary to limit the depth at which the lava is formed by the depth at which earthquake is generated? It seems quite unnecessary to adopt this limitation. The lava does not come to the top of Vesuvius, or Teneriffe, because of earthquake-shock, but by reason of pressure adequate to sustain the liquid column. This pressure on the lava may be exercised by steam, and steam may rend the rocks above it, and cause the earth to shake; but there is no logical tie which fixes these operations to be at the same depth. The origin of lava may be very much lower than the fissuring of rocks above it.

In fact, whoever considers the circumstances of the outpouring of lava, from age to age, at intervals in Ætna, or Hecla, or the perpetual exhibition of it in Stromboli, or the suddenly uplifted streams of Vesuvius, cannot fail to perceive that in all these and all other cases of active volcanos the liquid mass of rock is always ready to be poured out, upon the access of adequate pressure.

The earthquake, no doubt, is an evidence of such pressure, and may open or reopen fissures by which the lava is reached from above, and channels by which it can be pressed up to day-light from below; and, no doubt, heat in some way maintains the liquidity of lava, and generates the force of the earth-wave; but the

lava may be fused by means of heat ascending from below, and the steam-power be excited by means of water descending from above.

A temperature of 2000° would be found, according to the ordinary computation, at 20, 21, or 22 miles of depth. Here must be, if not a general mass of internal fluid rock, at least a limited tract of subterranean lava, ready to ascend on the application of adequate pressure.

If steam be the agency through which the pressure is applied, it must be supposed to be generated in great quantity, and be supplied by great reservoirs of water; for steam acts by quantity as well as pressure, and its effects are proportioned thereto.

If we take such a mountain as that of Teneriffe, for example, containing a column of lava raised above the sea-level 12,000 feet, with a specific gravity of 2·75[d], this will press at the surface of the earth, with the weight of a column of water 33,000 feet in height, and would balance a steam pressure of 1,000 atmospheres. Such a pressure would be generated by a temperature of 1207°, and this would probably occur under Teneriffe, as an effect of the earth's heat, at a depth of 68,400 feet = 13 miles. By the same rule, the ejection-force in Chimborazo, 21,100 feet, would balance a column of water 57,750 feet, or 1,623 atmospheres. This would be generated

[d] The lava which has flowed from the Peak is usually of the nature of obsidian; and is of less specific gravity than that here assumed for the purpose of including a fair average of the whole column. The calculations which follow are offered as approximations, sufficiently ··upport the conclusion stated.

by a temperature of 1309°, and that might be reached under the American volcano at a depth of 70,800 feet, or 14 miles. In all known cases the steam pressure required may be had at a less depth than that required for rock-fusion by earth-heat.

This being the view of the statical action of steam in sustaining a column of lava above the general level of the surface of the earth, we may turn to the dynamic effect of the same agent in causing the outflow of the lava, either at the summit or on the flanks of a mountain, and the ejections of stones, scoriæ, ashes, vapours, and gases which precede, accompany, and follow an eruption of lava. The last-mentioned phænomena furnish indeed more information as to the chemical effects which accompany volcanos than any measure of the 'work' done by volcanic agency in a mechanical form. Still, the perpetual cloud which overhung Vesuvius for more than half a year gives at least indication of the enormous quantity of water boiled off in the hot pipes of the mountain, and leads to important questions as to the source of the liquid, the subterranean channels which it indicates, and the degree in which it can be supposed to be mixed with the melted rock, and to be present in the solidified lava.

Sir W. Hamilton, among many valuable records of observation of Vesuvius, narrates that he witnessed the upthrow of masses from the crater which occupied 11″ in falling to the same level. During the eruption of March and April, 1868, Mr. Lee and myself observed with a telescope at night the time occupied in falling

by many such ejected masses, and counted 6, 7, 8, 9, 10, and 11″—the last only once. These were large luminous masses. The height from which they fell was at a maximum $= 11^2 \times 16\frac{1}{12} = 1946$ feet. Probably this is rather too great, on account of the uprushing current of steam, which would somewhat retard the fall. The velocity at which the stones left and returned to the crater would be 350 feet in a second of time.

By another of Sir W. Hamilton's observations we learn that at Pompeii, 6 miles from the crater of Vesuvius, among the heaps of ashes and scoriæ were found stones 8 lbs. in weight. These stones must have been projected through the air from the ancient eruption in A.D. 79, from the old crater of Somma which, being very large, may be supposed to have projected them at an angle deviating much from the vertical. Taking the most favourable supposition of all, that of projection at an angle of 45° from the level of the sea, the stones would describe a parabolic curve rising to one mile and a-half at the vertex, move with a velocity of 1,000 feet per second, and occupy 45″ of time in the flight.

If these stones had started from the level of the sea, and had been directed vertically, they might have gone upward for 31·5″ of time, and have reached a height of 14,560 feet. This may be regarded as indicating a force superior to that already calculated for Teneriffe, unless the 'stones' observed by Sir W. Hamilton were more than usually cellular.

'opic observations already referred to, satisfied

me that the stone-throwing of Vesuvius arose from explosive forces near the upper surface of the lava; this was consistent with the often expanding stream of upshooting stones, and with the pauses and renewals of the action. If we might introduce here an idea which perpetually presents itself; the cause of these sudden and capricious explosions may be not the heating of the water-bubbles which explode, but the cooling of them, below the 'spheroidal' state, to some red heat which admits of their collecting together and assuming the normal condition of vapour: whereas lower down in the lava the bubbles of water, inclosed in the lava, are too much heated to be allowed to 'flash into steam.' By this consideration we see that steam-power cannot be generated *in lava*, to beyond a certain measure of intensity, depending on a limited temperature [e].

[e] On the presence and effects of moisture in lava, the remarks of Mr. Scrope, in his Treatise on Volcanos (ed. 2), may be consulted.

CHAPTER X.

MINERALS OF VESUVIUS.

'Il numero di tutte le specie da noi descritte, mostra quanto la orittognosia Vesuviana abbia finora progredito per le nostri mani.'

MONTICELLI E COVELLI, 1825.

THE products of Vesuvius contain, in various forms and different combinations, many of the elementary sorts of matter with which we are familiar in rock, water, and air. Not all these substances, but a proportion of them, larger probably than can be authentically quoted from any other single mountain of the world. The following list embraces the elementary substances found in Vesuvius, with numerical expressions for specific gravity, combining weight and temperature of fusion.

The column expressing fusion is unfortunately at once the most interesting, and the least complete; but it includes some of the most important data. The number for iron is perhaps the least to be depended on, experiments having rarely been practicable on pure iron. There is a diversity of statements in regard to the · of zinc.

Metallic, *sixteen;* the whole number at present known to chemists being *fifty*.

	Specific Gravity.	Combining Weight.	Centig. Temp. of Fusion.
E Aluminium	2·56	27·5	....
Arsenic	5·9	75·0	*v*
E Calcium	1·58	40·0	....
* Cobalt	8·95	58·5	....
Copper..........	8·9	63·5	1090°
Iron	7·8	56·0	1600°
Lead	11·3	207·0	327°
A Lithium	0·593	7·0	....
Magnesium.	1·75	24·0	*v*
Manganesium....	8·0	55·0	....
A Potassium	0·865	39·0	60°*v*
A Sodium	0·972	23·0	100°*v*
Titanium........	....	50·0	....
† Uranium........	18·4	120·0	....
Zinc............	7·1	65·0	360°
Zirconium	....	89·5	....

Non-Metallic, *ten;* the whole number known to chemists being *fourteen*.

	Specific Gravity.	Combining Weight.	Centig. Temp. of Fusion.
‡ Boron	....	11·0	
Carbon	....	12·0	
Chlorine	....	35·5	
Fluorine	....	19·0	
Hydrogen	....	1·0	
Nitrogen........	....	14·0	
Oxygen	....	16·0	
Phosphorus......	....	31·0	45°
Sulphur	....	32·0	115°
Silicon..........	2·49	28·0	

(A) The prefix A indicates the metallic bases of alkalies.
(E) ,, E ,, ,, earths.
(*v*) *v* in the column of fusion indicates vaporizable at or below a red heat. * Noticed by Davy in 1820.
† Noticed by Monticelli, in Uranite?
‡ In the tourmaline, quoted from Pompeii by Lyell, and in boracic acid of the eruption of 1817 by Monticelli.

These twenty-six simple or elementary substances compose the solid, liquid, and aëriform bodies which are obtained among the volcanic products of Vesuvius and Somma. They include no elements of special rarity; they contain neither gold nor silver; no antimony, bismuth, or nickel have been observed — substances so common in mineral veins; no mercury, palladium, or platinum.

The crust of the earth, as known to geologists, consists mainly of a few elements, variously combined, viz.

Oxygen, about one half	50·0
Silicon, about one fourth	25·0
Aluminium, about one sixteenth	6.0 [a]
Calcium, one twentieth	5·0
Iron, one twenty-fifth	4·0
Magnesium, one thirtieth	3·0
Sodium, one fortieth	2·5
Potassium, one fortieth	2·5

The substances named are the most abundant of the elements of rocks and minerals in Vesuvius.

Various other elements	2·0

Some of the minerals of Vesuvius are peculiar to this locality, others are more frequent here than elsewhere; but still the main substance of the solid products is composed of felspathic or leucitic, and augitic or hornblendic minerals, in this respect agreeing with what

[a] This estimate of the quantity of aluminium may appear low, but in most 'clays' there is more, usually very much more, silica than alumina.

geologists have called 'Trap' rocks, 'greenstones,' 'diabase,' &c. They are for the most part basic compounds, silicates of alumina, lime, magnesia, iron, &c, in which the silica is not in so large a proportion as in the constituents of granite.

We obtained nearly complete collections of these minerals at Naples, and the specimens have been examined while drawing up the following notices, which comprehend such of the chemical and physical characters as appeared likely to be useful to the explorers of Vesuvius, or important in reference to the theory of volcanic action.

There is, I believe, no descriptive catalogue of Vesuvian minerals accessible to the English reader; nor are the lists which are sometimes given, such as that in Dr. Daubeny's treatise on Volcanos, sufficient for the student. It has appeared useful to draw up a brief systematic catalogue, and to add some illustrations of the principal crystalline forms.

English chemists have not occupied themselves in any considerable degree with the analysis of Vesuvian minerals; nor are special collections of these minerals common in our museums. But in the 'Mineralogy' of W. Phillips, especially in the editions by Miller, and in Nicol's 'Mineralogy,' the student will find a large proportion of the known volcanic minerals referred to Somma, or old ejected masses, or to the more modern lava-currents. In these works, also, the analyses of Vesuvian minerals are given with care to the date of the publication, and I have obtained

some additional information from later, especially Italian writers.

In works devoted to mineralogy, a peculiar symbolical language, the invention of Naumann, is employed in the description of crystals; but different symbols being chosen by different authors, which would have required a small treatise to explain, it has been thought best to omit them. For a similar reason, the symbols of chemical constitution, on which, as applied to minerals, there is still some want of agreement among atomists, have not been introduced. Wherever practicable, the analyses of Vesuvian specimens have been recorded.

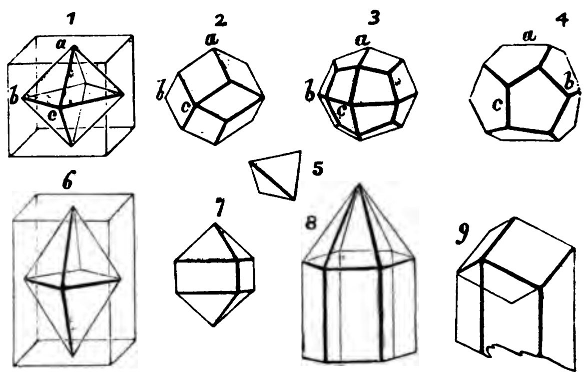


Diagram XXXIII. First, Second, and Third Systems of Crystallization.

A few words on the crystalline systems of form, to which in the following pages Vesuvian minerals are referred, will be useful. The diagrams presented above

represent the three first systems, viz. the tessular system, figs. 1, 2, 3, 4, 5; the square system, figs. 6, 7; and the hexagonal system, figs. 8 and 9.

The diagrams which follow represent the three remaining systems, viz. the rhombic, figs. 10, 11; the monoclinic, fig. 12; and the anorthic, fig. 13.

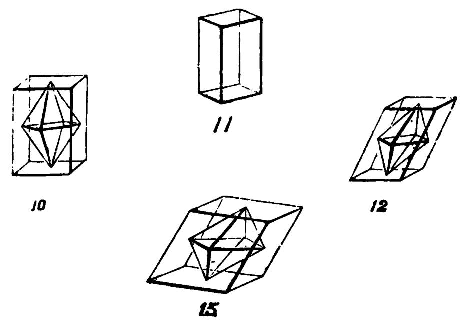


Diagram XXXIV. FOURTH, FIFTH, AND SIXTH SYSTEMS OF CRYSTALLIZATION.

The six systems of crystalline mineral forms may be defined with reference to their axes of symmetry, and may always be regarded as prisms of four or six sides—or as double pyramids having a certain dependence on such prisms.

Thus the prism of the first system is the cube, represented in fig. 1, whose three axes joining the centres of opposite faces are equal, and are at right angles to one another. These axes are situated as the letters *a*, *b*, *c* indicate.

The double pyramid of this system is the regular octahedron, also represented in fig. 1, where the six solid angles of the octahedron are seen to touch the centres of the six faces of the cube internally; so that this figure can be understood to have the same axes as the cube. The crystals are represented as transparent. The eight equilateral sides of the octahedron replace the eight solid angles of the cube.

Again, fig. 2 shows the aspect of the rhomboidal dodecahedron, with six of its solid angles—those with four planes at each angle—coincident with the terminations of the three axes *a b c*, and its twelve rhomboidal faces replacing the edges of the cube.

Fig. 3 represents a crystal of 24 plane sides, which are trapezoidal in form; six of its solid angles with four planes at each angle touch the six cubical faces internally at the ends of the three axes *a b c*; twelve other solid angles, with four planes each, replace the twelve edges of the cube, and eight three-faced solid angles replace the eight solid angles of the cube.

Fig. 4 is the pentagonal dodecahedron, six of whose edges lie in faces of the cube, and are parallel to the three axes of that figure; eight of its solid angles replace the eight angles of the cube, twelve other solid angles being at the terminations of the six edges which lie in the faces of the cube.

These five types of form, all regular, except fig. 4, and all parts of one equi-axed system, may be named and employed to designate crystals, under the names

of the cube, octahedron, rhombo-dodecahedron, 24-trapezohedron, and penta-dodecahedron.

These are not all the symmetrical solids which can be included in the system, and really occur in nature, though not in Vesuvius. One, the regular tetrahedron, may be represented in the cube by placing its four solid angles opposite four alternate angles of the cube, and making its six edges coincide with diagonals of the six cubical faces. (See fig. 5.)

The Vesuvian minerals which are crystallized according to the *first* system, in one or other of the types, variously modified, is 18. Among them the penta-dodecahedron and tetrahedron are very rare. These minerals are,—

Iron Pyrites ..	cubic	Periclase ..	octahedral
Lead Sulphide ..	„	Spinel	„
Zinc Sulphide ..	„	Leucite ..	24-trapezohedron
Fluor	„	Sodalite ..	rhombo-dodecahedron
Ammoniac chloride	octahedral		
Sodic chloride ..	cubic	Haüyne	„
Potassic chloride ..	„	Lapis lazuli ..	„
Oxydulous iron ..	octahedral	Analcime ..	24-trapezohedron
Iserine	„	Garnet	rhombo-dodecahedron, and 24-trapezohedron.
Cuprite	„		

The *second* system of crystals is composed of square prisms whose vertical axis is never equal to, but always greater or less than the horizontal axes to which it is perpendicular, these being equal and at right angles to one another, and of square pyramids having a geometrical relation to the prisms.

In fig. 6 such a prism is drawn, and within it an

octahedron or double pyramid, whose solid angles meet the inner faces of the prism centrally.

Another pyramid may be drawn whose solid angles at its base meet the inner edges of the prism centrally.

In fig. 7, a portion of prism is represented, terminated by two opposite pyramids, which if they were prolonged to meet would make an octahedron.

To this series of forms the most convenient general title is the square or tetragonal system, the horizontal surfaces of its prism being squares, and its vertical surfaces parallelograms but not squares. The principal types may be defined as prisms, pyramids, and octahedrons, or combinations of these. Different species of minerals have their pyramidal faces inclined at different angles.

The Vesuvian minerals which are crystallized according to this system are eight in number, viz.:—

Double Sulphide of Iron and Copper, Scapolite, Mizzonite, Sarcolite, Gehlenite, Humboldtilite, Idocrase, Zircon.

For the *third* crystalline system the titles of hexagonal and rhombohedral have been given, one derived from the form of the prism, the other from the remarkable six-sided solid, a kind of double pyramid, two of whose solid angles coincide with the axis of the prism, and the six others lie in its edges, while all the edges of the rhomboid lie obliquely in faces of the prism.

Fig. 8 shows a prism with a six-sided terminal

pyramid; and fig. 9 another prism with a trihedral summit, the opposite faces to which are shown, so as to complete the rhomboid.

The Vesuvian minerals which belong to this system are twelve in number, viz.:—

Magnetic Iron Pyrites, Covellinite, Graphite, Quartz, Calcite, Dolomite, Breunnerite, Apatite, Nepheline, Davyne, Biotite, Tourmaline.

The *fourth* system of crystals has its three axes at right angles to one another, but they are all unequal: the prisms may be rectangular, in which case three sets of unequal edges occur; or rhombic, in which two sets of edges are equal.

Fig. 10 shows the rectangular prism, with its included octahedron or double pyramid; and fig. 11, a similar representation of the rhombic prism.

The following ten minerals are crystallized according to this system:—

Sulphur, Iron Sulphide (Marcasite), Orpiment, Copper Chloride, Lead Chloride, Göthite, Zeagonite, Arragonite, Thomsonite, Olivine.

The remaining systems of minerals have their axes unequal: of these, one, the fifth, or oblique, or monoclinic system, has one of its axes perpendicular to the other two; but these are not at right angles to each other. Thus in fig. 12 the axis *b* is at right angles to the axes *a* and *b*, but these two are inclined to each other, at some angle different from 90°. The included octahedron or double pyramid has its solid angles in the centres of the prism faces.

The Vesuvian minerals included in this *fifth* type comprise thirteen species, viz.:—

Realgar, Atacamite, Copper Carbonate, Lime Sulphate, Orthoclase, Rhyacolite, Mica, Hornblende, Pyroxene, Wollastonite, Humite, Sphene, Guarinite.

The *sixth* system, called anorthic, or doubly oblique, has its three axes unequal, and neither of them perpendicular to another. The inclinations of two axes are, in some minerals, not considerably different from 90°; so that the few forms of this the least regular system cannot always be easily separated from those of the fifth system. Fig. 13 will sufficiently explain the form of the prism and its related octahedron.

The Vesuvian minerals of this system are only four, viz :—

Copper Sulphate, Labradorite, Anorthite, Boracic Acid.

Very few of the elementary substances mentioned p. 267 exist uncombined with others. Taking first those which are solid at ordinary temperatures, and considering them under natural divisions, we have the following results :—

Of '*Native metals*,' none, so far as is known, occur pure or uncombined with sulphur, chlorine, oxygen, &c.

Of '*Metallic alloys*,' meaning by this term mixtures of pure metals, without sulphur, oxygen, &c., none have occurred to our observation.

Sulphur, pure, and crystallized, is mentioned in the lists of Vesuvian minerals, and is supplied by the collectors and guides at Resina and at the Royal Museum,

associated with gypsum. It is not mentioned as 'native' in Dr. Daubeny's list (Volcanos, p. 236, 2nd ed.). It may, however, be regarded as sublimed at particular times in the eruptions. In the Solfatara it is evolved continually in association with hydrogen, and is deposited in considerable quantity.

Sulphides, compounds of sulphur with metals, occur in the Vesuvian products, but not plentifully, most of them being found only in 'ejected blocks'—ejected from the deepest parts of the volcano—which are parts of old mineral veins or metalliferous rocks.

Iron Sulphide—'Pyrrhotine,' 'Magnetic Iron Pyrites'—is found in Vesuvian lavas, and meteoric stones, according to Nicol (Mineralogy, p. 453). *Rare.*

Chemical composition—iron 60·5, sulphur 39·5.
Crystallization—hexagonal (usually short six-sided prisms).
Specific gravity—4·5 ±.
Hardness—4·0 ±.
Colour—reddish-yellow.
Effects of heat—fusible. In open tube yields sulphurous vapours.
Soluble in hydrochloric acid.

Iron Bi-sulphide—'Marcasite,' 'Leberchisa amorfa,' Liver-coloured Pyrites—in cavities of ejected blocks. *Rare.*

Chemical composition—iron 46·0, sulphur 54·0.
Crystallization—rhombic (usually flat prisms).
Specific gravity—4·8 ±.
Hardness—6·0 to 6·5.
Colour—yellowish, greyish.
Effects of heat—fusible. In closed tube yields sulphur.
Soluble in nitric acid.

Iron Bi-sulphide—'Common Pyrites'—found in cavities of lava. *Rare.* Monticelli is the authority.

Crystallization—cubical.
In other respects like marcasite.

Double Sulphide of Iron and Copper—'Chalcopyrite,' Copper Pyrites—found in ejected blocks. *Rare.*

Chemical composition—copper 34·5, iron 30·5, sulphur 35·0.
Crystallization—tetragonal.
Specific gravity— 4·2 ±.
Hardness—3·5 to 4·0.
Colour—yellow.
Effects of heat—fusible. In open tube evolves sulphurous fumes.
Soluble in a mixture of hydrochloric and nitric acid.

This is the common copper ore of Cornwall, and of many other countries rich in mineral veins.

Covellinite—a sulphide of copper—is noticed as a Vesuvian product by Beudant.

Chemical composition—copper 66·4, sulphur 33·6.
Cystallization—hexagonal.
Specific gravity—3·8.
Hardness—under 2·0.
Colour—blue.
Fusible.
Soluble in nitric acid.

Lead Sulphide—'Galena'—is found in ejected blocks, as probably portions of ancient metalliferous veins. Our specimen is a vein enclosed in fine-grained and mixed with large-grained crystallized calcite and blende.

Chemical composition—lead 86·7, sulphur 13·3.
Crystallization—tesseral (usually cubical).
Specific gravity—about 7·5.
Hardness—2·5.

Colour—gray; the streak dark gray.
Effects of heat—fusible, with loss of sulphur.
Soluble in nitric acid.

Red Sulphide of Arsenic—'Realgar'—occurs minutely but well crystallized in the fumaroli of Vesuvius and Solfatara; mostly a product of sublimation with hydrogen.

Chemical composition—arsenic 70·0, sulphur 30·0.
Crystallization—monoclinic (usually in prisms).
Specific gravity—about 3·5.
Hardness—less than 2·0.
Colour—orange-red; streak orange.
Effects of heat—volatilized at moderate temperature.
Soluble with difficulty in nitric acid.

Yellow Sulphide of Arsenic—'Orpiment'—occurs in the same circumstances as realgar.

Chemical composition—arsenic 61·0, sulphur 39·0.
Crystallization—rhombic (short prisms).
Colour—yellow.
In other respects like realgar.

Zinc Sulphide—'Blende'—occurs in ejected blocks.

Chemical composition—zinc 67·0, sulphur 33·0.
Crystallization—tesseral (often tetrahedral).
Specific gravity—about 4·0.
Hardness—under 4·0.
Colour—usually brown or black.
Lustre—brilliant.
Effects of heat—almost infusible.
Soluble in nitric acid.

Fluoride of Calcium—'Fluor spar'—is mentioned in ejected blocks. Fluorine occurs in some other minerals of Vesuvius.

Chlorides usually appear by sublimation about the end of an eruption, and form incrustations on the inner surfaces of lava channels and fissures. They are not included in Dr. Daubeny's list.

Hydro-chloride of Copper—'Atacamite'—has been found incrusting lavas of A.D. 1820 and 1822, most frequently at La Scala near Portici.

Chemical composition — copper-protoxide 72·0, hydrochloric acid 16·0, water 12·0.
Crystallization—rhombic (in small prismatic crystals).
Specific gravity—about 4·0.
Hardness—under 3·5.
Colour—green.
Effects of heat—loss of water, fusion.
Soluble in acids.

Chloride of Lead—'Cotunnite'—found in the fissures of the Vesuvian lava of A.D. 1817 and later years, and again in A.D. 1855; and in the crater after the eruption of A.D. 1822.

Chemical composition—lead 74·5, chlorine 25·5.
Crystallization—rhombic (needle-shaped).
Specific gravity—5·2.
Hardness—3·0.
Colour—white.
Effects of heat—fusible, volatilizable.
Soluble in acids, and in much water.

Ammoniacal Chloride—'Sal ammoniac'—not frequent, in crevices of lava after great eruptions.

Chemical composition—ammonia 33·7, hydrochloric acid 66·3.
Crystallization—tesseral (octahedral or cubical).
Specific gravity—1·5.
Hardness—under 2·0.

Colour—tinted variously. Transparent.
Effects of heat—volatilizes.
Soluble in water.

Chloride of Sodium—'Common Salt'—frequent in crevices of lava after eruptions.

Chemical composition—sodium 40·0, chlorine 60·0.
Crystallization—tesseral (cubic forms prevail).
Specific gravity—2·1.
Hardness—2·0.
Colour—variously tinted. Transparent.
Soluble in water.

Chloride of Potassium is noticed by Miller as an efflorescence on lava, and as crystallized in the cubic form.

Graphite—Plumbago—is included in the list of minerals of Vesuvius by Monticelli. Ejected blocks. *Very rare.*

Oxides occur among ejected blocks, and dykes of Somma, and in lava-fissures; the most prevalent being 'Ferro oligisto,' 'Specular' iron, or Hæmatite.

Boracic acid—observed in the eruption of A.D. 1817. (Monticelli and Covelli.)

Quartz—or pure silica—is a rare product of Vesuvius; found by Monticelli in cavities of ejected blocks, belonging to the eruption of A.D. 79, in the Fosso Grande, also in a lava-current at Pollena, on the slope of Monte Somma.

Stalactitic quartz is mentioned by Hamilton as being found in small globules in the lava of A.D. 1767.

Chemical composition—silicon 46·63, oxygen 53·33.
Crystallization—hexagonal (usually in prisms).

Specific gravity—2·6.
Hardness—7·0.
Colour—variously tinted. Transparent.
Infusible. Insoluble in acids, except the 'hydrofluoric.'

Magnetite—'Oxydulous Iron'—occurs in blocks in Somma, and in volcanic sand near Bosco Reale.

Chemical composition—iron 72·4, oxygen 27·6.
Crystallization—tesseral (usually octahedral).
Specific gravity—5·0.
Hardness—6·0.
Colour—black.
Fusible with difficulty.
Soluble in hydrochloric acid.

Titaniferous magnetite (Iserine) occurs in plenty on the shore of Resina, Torre del Greco, &c., and in rivulets descending from Vesuvius and Somma. It is found also disseminated in lava, scoriæ, and tufa.

Göthite—'Hydrous Oxide of Iron'—is mentioned in ejected blocks and dykes of Somma.

Chemical composition—peroxide of iron 90·0, water 10·0.
Crystallization—rhombic (usually in prisms).
Specific gravity—about 4·3.
Hardness—5·0.
Colour—brown.
Effects of heat—fusible.
Soluble in hydrochloric acid.

In examining this substance by solution in hydrochloric acid, fine siliceous fibres were found in the liquid.

Cuprite—'Red Oxide of Copper'—was found incrusting some slags ejected by Vesuvius. (Nicol's Min. p. 430.)

Chemical composition—copper 88·9, oxygen 11·1.
Crystallization—tesseral (often octahedral).

Specific gravity—5·8 to 6·0.
Hardness—under 4·0.
Colour—red. Often translucent.
Fusible.
Soluble in hydrochloric acid, and in ammonia.

Uranite—Oxide of Uranium—is mentioned by Monticelli, in his Prodromo della Mineralogia Vesuviana, as occurring in small bright green laminæ in cavities of lava—but with some doubt.

Carbonates occur, not plentifully, mostly in fissures or cavities of lava; some are ejected masses, found on Monte Somma.

Copper Carbonate, called 'Malachite' in Neapolitan catalogues, from Monte Somma—with minute rhomboids and other forms of calcite.

Chemical composition (probably)—copper 71·8, carbonic acid 20·0, water 8·2.
Crystallization—monoclinic, but rarely traceable.
Specific gravity—under 4·0.
Hardness—under 4·0.
Colour—green.
Fusible on charcoal.
Soluble in acid, even slightly in water saturated with carbonic acid.

Carbonate of Lime occurs among the ejected masses as *limestone*, and crystallized as *calcite*.

Chemical composition when pure—lime 56·1, carbonic acid 43·9; or calcium 40·0, oxygen 48·0, carbon 12·0.
Crystallization—rhombohedral (usually in prisms or rhomboids).
Specific gravity—2·7.
Hardness—3·0.
Colour—white, or tinted variously.
Infusible in open fire.
Soluble in acids.

Arragonite, also a carbonate of lime, crystallized, found in cavities of lava in Monte Somma.

Crystallization—rhombic (usually acicular prisms in radiating tufts).
Specific gravity—under 3·0.
Hardness—under 4·0.
Colour—white.
In other respects like calcite.

Dolomite—metamorphic limestone probably—is found among ejected masses in Monte Somma.

Chemical composition—carbonate of lime and carbonate of magnesia intimately combined.
Crystallization—rhombohedral.
Specific gravity—about 2·9.
Hardness—often greater than that of calcite (4·5).
Colour—pure white.
Infusible. Slowly soluble in acids.

Breunnerite, or Giobertite, a magnesian carbonate, found very rarely in ejected blocks.

Chemical composition—carbonate of magnesia with admixtures of carbonate of iron and carbonate of manganese. Carbonate of magnesia 87·0, carbonate of iron 13·0.
Crystallization—rhombohedral.
Specific gravity—about 3·0.
Hardness—greater than that of calcite (4·5).
Colourless, or tinted variously.
Soluble slowly in acids.

Phosphates are represented by one interesting mineral, Apatite.

Apatite, or Phosphate of Lime, is found crystallized in ejected blocks and lava on the slope of Somma near Pollena.

Chemical composition—lime 55·0, phosphoric with small quantities of hydrochloric and fluoric acids 45·0.

Crystallization—hexagonal (usually in six-sided prisms).
Specific gravity—3·2.
Hardness—5·0.
Colourless, or tinted variously.
Fusible with difficulty.
Soluble in nitric and hydrochloric acid.

Sulphates—probably produced in a late stage of eruption or afterwards by the decomposition of sulphuretted hydrogen, the oxidation of the sulphur, and the action of the sulphuric acid on the earthy compounds of the lava.

Gypsum—'Gesso,' Sulphate of Lime—occurs mixed with sulphur.

Chemical composition—lime 32·6, sulphuric acid 46·5, water 20·9.
Crystallization—monoclinic.
Specific gravity—2·2 to 2·4.
Hardness—under 2·0.
Colour—white in the Vesuvian varieties.
Very sparingly soluble in water.

Cyanose—Sulphate of Copper—occurs sparingly on surfaces of lava.

Chemical composition—protoxide of copper 32·0, sulphuric acid 32·0, water 36·0.
Crystallization—anorthic.
Specific gravity—2·2 to 2·3.
Hardness—2·5.
Colour—blue. Translucent.
Soluble in water.

Magnesiates are represented by only one mineral, viz. Periclase, which occurs of a dark green colour in Monte Somma.

Chemical composition. It is little else than magnesia with some admixture of oxide of iron.
Crystallization—tesseral, only in octahedrons.

Specific gravity—3·75.
Hardness—6·0.
Colour—dark green.
Infusible.
Soluble in acids.

Aluminates are equally limited; only one species, viz. Spinel or Pleonaste, being found insulated in ejected blocks of Dolomite, in pale green granular augite, and mixed with mica and augite. Somma.

Chemical composition—alumina 72, magnesia 28.
Crystallization—tesseral (usually octahedral, the edges replaced by planes).
Specific gravity—3·4 to 3·8.
Hardness—8·0.
Colour—various, usually black.
Infusible.
Insoluble in acids.

Silicates. This large group of minerals may be conveniently arranged under several families; viz. Felspathic, Scapolitic, Leucitic, Zeolitic, Micaceous, Hornblendic, Grenatic, and Gems. Some of these families include both hydrous and anhydrous species.—Zeolites, always hydrous, offer such analogies to some of the other families that it may, perhaps, be preferable hereafter to distribute them as hydrosilicates among the other groups[b].

Felspathic Family. Combinations of Silica, regarded as an acid, with Alumina, Potash, Soda, Lime, Magnesia, Oxide of Iron, &c. The crystalline form is always oblique (monoclinic) or doubly oblique (anorthic).

[b] See on questions of felspathic affinity, St. Claire Deville, Ann. de Chimie; Abich on Volcanos; Sullivan in Jukes' Manual of Geology.

The *anhydrous group*, including Orthoclase, Rhyacolite, Labradorite, Anorthite; which all have a specific gravity about 2·6 or 2·7, and a degree of hardness represented by 6·0. They are all in some degree fusible.

Orthoclase occurs in ejected blocks in Somma and on Vesuvius; it is the glassy variety, called Sanidine.

Chemical composition of a Vesuvian specimen—silica 65·5, with alumina 19·2, potash 14·7 (trace of soda), lime 0·6.
Crystallization—monoclinic.
Specific gravity—2·56.
Hardness—6·0.
Usually colourless and translucent in the Vesuvian specimens.
Fusible with some difficulty.
Insoluble in acids.

Rhyacolite—Icespar—in ejected blocks, with augite, mica, and nepheline, on Vesuvius.

Chemical composition of a Vesuvian specimen—silica 50·3, alumina 29·4, soda 10·6, potash 5·9, lime 1·1, magnesia 0·23, peroxide of iron 0·28.
Crystallization—monoclinic.
Specific gravity—2·57.
Hardness—6·0.
Colour—white or gray.
Fusible.
Slightly soluble in hydrochloric acid.

Labradorite—a white variety occurs in the lava of Vesuvius. (Nicol's Mineralogy, p. 126.)

Chemical composition of a Vesuvian specimen analysed by Laurent—silica 47·9, alumina 34·0, soda 5·1, potash 0·9, iron peroxide 2·4, lime 9·5, magnesia (trace). It is, however, generally considered to have the same composition as rhyacolite.

Crystallization—anorthic.
Specific gravity—about 2·70.
Hardness—6·0.
Colourless or slightly tinted.
Fusible.
Soluble with difficulty in hydrochloric acid.

Christianite, or Anorthite, occurs in ejected blocks on Somma, in cavities of dolomite.

Chemical composition of specimens from Somma—silica 44·13, alumina 35·02, lime 17·9, magnesia 2·05, iron 0·6, potash 0·4, soda 0·4.
Crystallization—anorthic (crystals resemble those of Labradorite).
Specific gravity—2·73.
Hardness—6·0.
Colourless and translucent.
Fusible.
Soluble in hydrochloric acid.

The *Hydrous* group includes Pumice and Pitchstone, which are uncrystallized masses thrown out of several volcanos of Italy—the latter, however, being very rare in Vesuvius, while the former is abundant.

Pumice, a fibrous uncrystallized hydrosilicate of alumina, &c., with

Silica 72·0, alumina 15·0, potash 3·0, soda 3·0, lime 2·0, iron 2·0, water 3·0 or more.
Specific gravity—2·0.
Hardness—5·0.
Fusible.

Pitchstone, a glassy uncrystallized hydrosilicate of alumina, identical in composition with pumice.

Specific gravity—2·2.
Hardness—5·0.
Fusible.

This substance occurs, commonly in small pieces, partly pumiceous, on Monte Nuovo, in Astroni, &c.; rarely on Vesuvius.

Scapolitic Family. Silicates of the family of Scapolite are also essentially combinations of silica and alumina, with additions of soda, potash, lime, &c. The lime sometimes is in larger quantity than the alumina. Traces of water occur, and one, Davyne, is hydrous. Some of these minerals are crystallized, in the square prismatic (or tetragonal) system; and two in the rhombohedral (or hexagonal) system.

(a) Square prismatic group—some of the species differ very little even in the angles of their pyramids.

Scapolite (also called Meionite) occurs in cavities in ejected blocks on Somma and Vesuvius, with green augite or black hornblende.

Chemical composition (meionite), as given by Guiscardi — silica 42·8, alumina 31·5, lime 21·7, soda 1·3, potash 1·0, magnesia 0·9, oxide of iron 0·5, water (a trace).
Crystallization—square prisms of various lengths.
Specific gravity—2·7.
Hardness—5·5.
Colourless or tinted; glassy and transparent.
Fusible to glass.
Soluble in hydrochloric acid, and gelatinizes.

Mizzonite, a mineral allied to meionite, of the same crystalline structure, with nearly the same measures, was first described by Professor Scacchi [c], from Monte Somma. It has been recorded by Professor Guiscardi in

[c] Mem. Geol. sulla Campagna, 1849.

his paper on Piperno[d], as forming part of that rock at Pianura. The chemical composition, in comparison with meionite, is given according to Von Rath for both the Somman and Pianuran specimens:—

	Somma.	Pianura.	Meionite.
Silica	54·70	62·72	42·8
Alumina	23·80	21·82	31·5
Lime	8·77	4·63	21·7
Soda	9·83	9·37	1·3
Potash	2·14	1·15	1·0
Oxide of Iron, Magnesia ..	trace	trace	1·4

The three minerals here compared have nearly the same crystallographic angles; measures at the summits of the octahedrons give—Somma, 135° 59′; Pianura, 136° 0′; Meionite, 136° 11′. (Guiscardi.)

The composition of the specimens from Somma and Pianura is akin to that of the felspars, especially to oligoclase.

Specific gravity of mizzonite—2·53 to 2·62.

In other respects very like meionite.

Humboldtilite—'Mellilite,' 'Somervillite,' 'Zurlite,' &c.—occurs in gray micaceous lava of Somma, and ejected blocks.

Chemical composition—silica 38·0 to 44·0, alumina 6·0 to 11·0, lime 32·0, soda and potash 4·0, magnesia, oxide of iron, &c. 3·0 to 16·0.

Crystallization—square prismatic (in short thick prisms, often curved on the surfaces so as to look as if bedewed with honey or gum).

Specific gravity—2·9.

[d] Transactions of the Royal Academy of Naples, 1867.

Hardness—5·5.
Yellowish; translucent.
Fusible to glass.
Gelatinizes with hydrochloric acid.

Sarcolite, in ejected blocks with Wollastonite, hornblende, &c. It is perhaps identical with Humboldtilite.

Chemical composition—silica 42·1, alumina 24·5, lime 32·4, soda 2·9.
Crystallization—tetragonal (square prisms.)
Specific gravity—2·55.
Hardness—6·0.
Pale pinkish; translucent.
Fusible.
Gelatinizes with acids.

Gehlenite is mentioned by Monticelli among the products of Pollena, on the slope of Somma. It resembles Humboldtilite, contains 30 per cent. of silica, and crystallizes in flat-topped prisms.

(b) Hexagonal group—two species hardly differing except in the proportion of water, their crystallization being reducible to the same rhombohedral elements.

Nepheline (Cavolinite, &c.)—found in ejected blocks on Somma, with icespar, garnet, and mica.

Chemical composition of specimens from Somma—silica 44·0, alumina 34·0, soda 16·0, potash 4·5, lime 2·0. Traces of oxide of iron, water, &c.
Crystallization—hexagonal (in small prisms with flat summits).
Specific gravity—2·6.
Hardness—5·5 to 6·0.
Colourless, translucent.
Fusible to glass.
Gelatinizes in hydrochloric acid.

Davyne, a hydrous nepheline, is found in cavities of ejected blocks of gray lava on Somma, and at Bosco Reale.

Chemical composition—silica 42·9, alumina 33·3, iron oxide 1·2, lime 12·0, water 7·4, loss 3·2.
Crystallization—hexagonal (in prisms).
Specific gravity—2·44.
Hardness—5·0 to 5·5.
Colourless, or reddish. In our specimen reddened at the trihedral summit only.
Fusible to glass.
Gelatinizes in hydrochloric acid.

Silicates of the Family of Leucite. Compounds of silica and alumina, with additions of potash, soda, lime, and usually some hydrochloric or sulphuric acid. Crystals always of the regular or tessular type, in dodecahedral or 24-hedral forms[e].

Leucite, or Amphigene, frequent in the lavas of Somma, and ejected blocks: less frequent in Vesuvian lava. Little known beyond Italy.

Chemical composition—silica 56·0, alumina 23·0, potash 20·0, soda and loss 1·0.
Crystallization—tesseral. (Only form yet found is the 24-trapezohedron—Diagram XXXIII. fig. 3.)
Specific gravity—2·45.
Hardness—under 6·0.
Colour—white. Translucent.
Infusible.
Soluble in hydrochloric acid.

[e] See on questions of leucitic and zeolitic affinity St. Claire Deville, Ann. de Chimie.

Sodalite, found in ejected dolomitic blocks, and in lavas of Somma, with augite and icespar.

Mean chemical composition of Vesuvian specimens—silica 38·6, alumina 28·9, soda 28·2, iron oxide (trace), hydrochloric acid 4·3.
Crystallization—tesseral (in the form of a rhomboidal dodecahedron, or the same with six faces elongated).
Specific gravity—2·28.
Hardness—5·5.
Colourless or tinted.
Fusible.
Gelatinizes with acids.

Haüyne, or Latialite, occurs disseminated and in cavities of gray micaceous or augitic lava. Somma.

Chemical composition—silica 32·4, alumina 27·8, lime 10·0, soda 4·2, potash 2·4, sulphuric acid 13·0.
Crystallization—tesseral (only known in the form of rhomboidal dodecahedrons).
Specific gravity—2·45.
Hardness—5·25.
Colour—pale blue. Translucent.
Fusible to glass.
Soluble in hydrochloric acid.

Lapis lazuli—in ejected blocks. Somma.

Chemical composition—silica 45·5, alumina 31·8, soda 9·1, lime 3·5, iron and peroxide 1·8, chlorine (a trace), water (trace), sulphuric acid 5·9.
Crystallization—tesseral (but usually in indistinct or granular masses).
Specific gravity—2·4.
Hardness—5·5.
Colour—rich blue.
Fusible.
Soluble in hydrochloric acid, and gelatinizes.

Silicates of the Family of Zeolite. These contain 'water of crystallization' in essential and considerable proportion, as from 8 to 18 per cent. The silica is combined with alumina, and variable proportions or replacements of soda, potash, and lime.

The crystallization is either on the tessular pattern, or the square prismatic, or the rhombic system. The group is not natural.

Analcime, or Cubic Zeolite, is found in drusy cavities of ejected blocks. One of its forms agrees with that of leucite, and in composition it seems to differ chiefly by containing water, and soda instead of potash.

Chemical composition—silica 55·0, alumina 23·0, soda 14·0, water 8·0.
Crystallization—tessular (in 24-sided crystals with trapezoidal faces).
Specific gravity—2·2.
Hardness—5·5.
Colour—white. Translucent.
Fusible.
Soluble, and gelatinizes in hydrochloric acid.

Thomsonite, or Comptonite—in ejected blocks of gray lava, with augite, leucite, analcime—often in drusy cavities.

Chemical composition—silica 37·9, alumina 31·4, lime 12·7, soda 5·2, water 12·3, trace of magnesia and iron.
Crystallization—rhombic (usually a short eight-sided prism, with flat summit).
Specific gravity—2·35.
Hardness—5·0 and upwards.
Colour—white. Translucent.
Fusible.
Soluble, and gelatinizes in hydrochloric acid.

Zeagonite, or Gismondine—in ejected blocks and dykes of Somma, crystallized in cavities.

Chemical composition of a Vesuvian specimen—silica 36·0, alumina 27·0, lime 13·0, potash 3·0, water 21·0.
Crystallization—square prismatic, in octahedrons.
Specific gravity—2·2.
Hardness—4·5.
Colour—bluish white. Translucent.
Fusible.
Gelatinizes in hydrochloric acid.

Prehnite is included by Monticelli in his Catalogue of Vesuvian Minerals, as occurring in limestone.

Stilbite is mentioned as having been collected by Maclure, from lava at Torre del Greco, and determined by Brocchi.

Silicates of the Family of Mica. In composition they often closely resemble garnet. Their usual crystalline form is a short lamellar prism.

Potash Mica—not unfrequent in ejected blocks; rare in some lava of Vesuvius.

Chemical composition of a Vesuvian specimen—silica 40·9, alumina 17·8, potash 10·0, magnesia 19·0, iron peroxide and protoxide 11·0, lime 0·3. (Fluoric acid is mentioned in some potash mica.)
Crystallization—monoclinic. Crystals six-sided. Tabular, or very short prisms.
Specific gravity—about 3·0.
Hardness—variable, 2·0 to 3·0.
Colour of the Vesuvian specimens—dark or pale green, or black.
Fusible—not easily.
Insoluble in acids.

Magnesian Mica—'Biotite'—in ejected blocks.

Chemical composition of a Vesuvian specimen—silica 39·8, alumina 16·0, iron peroxide 8·3, magnesia 24·5, potash 8·8, water 0·8.
Crystallization—hexagonal (in short tabular prisms).
Specific gravity—about 2·9.
Hardness—2·0 to 3·0.
Colour—dark green.
Fusible—not easily.
Soluble in concentrated sulphuric acid, leaving white pearly plates of silica. (Nicol.)

Talc is mentioned among the minerals of Somma by Monticelli.

Silicates of the Family of Hornblende.

Hornblende, or Amphibole, including Breislakite—in ejected blocks and scoriæ, on Somma and Vesuvius, crystallized in cavities or mixed with other minerals.

Chemical composition—variable, owing to the diversity of the basic elements in combination—silica 40·0 to 60·0, alumina 0 to 18·0, magnesia 0 to 31·0, lime 0 to 16·0, iron protoxide 0 to 36·0, manganese, protoxide and peroxide 0 to 9·0, fluorine 0 to 1·5, water 0 to 3·5. This is not from Vesuvian hornblende.
Crystallization—monoclinic (usually six-sided prisms, obtusely terminated or flat-topped).
Specific gravity—about 3·2.
Hardness—about 5·5.
Colour of Vesuvian specimens—usually black, except Breislakite, which is brown and fibrous.
Fusible to glass.
Insoluble for the most part.

Augite, or Pyroxene—common in ejected blocks, and a constituent of the lava of Somma and Vesuvius.

Chemical composition of a Vesuvian crystal, agreeing well with another analysis of an Ætnæan specimen—silica 50·90, alumina 5·37, lime 22·96, magnesia 14·43, iron protoxide 6·25.
Crystallization—monoclinic (usually in six-sided prisms with oblique dihedral summits). Twin crystals occur in Somma.
Specific gravity—about 3·2.
Hardness—about 5·5.
Colour—dark green, light green.
Fusible.
Insoluble in acids.

Wollastonite, or Table-spar—in ejected blocks in drusy cavities and in the mass of lava—with augite.

Chemical composition—nearly the same as augite, but with lime almost exclusively for the base, silica 52·5, lime 47·5, with traces of magnesia, oxide of iron, and water.
Crystallization—monoclinic (in short tabular masses, or acicular prisms).
Specific gravity—about 2·8.
Hardness—5·0.
Colour—generally white.
Fusible with difficulty.
Gelatinizes in hydrochloric acid.

Silicates of the Family of Garnet. The composition of these minerals is extremely variable, through frequent replacements of the bases, alumina, iron oxide, manganese oxide, lime, and magnesia.

Garnet occurs not unfrequently among the minerals of Somma, in its usual dodecahedral crystals, of a red colour.

Chemical composition of a Vesuvian specimen—silica 39·5, alumina 13·3, iron peroxide 10·8, iron protoxide 3·6, manganese protoxide 1·4, lime 31·4.

Crystallization—tesseral. The form observed is the rhomboidal dodecahedron, of various magnitude.
Specific gravity—3·5 to 4·3.
Hardness—about 7·0.
Colour—usually red. Melanite, or black garnet, which is common near Rome, is quoted from Vesuvius by Monticelli.
Fusible to glass.
Very slightly soluble in hydrochloric acid.

Idocrase, or Vesuvian—frequent in ejected blocks. Somma.

Chemical composition of a Vesuvian specimen—silica 36·10, alumina 22·60, lime 33·50, iron protoxide 7·65, manganese protoxide 0·25.
Crystallization—square prismatic. The most common form a prism, with pyramidal summit, often truncated.
Specific gravity—about 3·5.
Hardness—6·5.
Colour—usually brown or yellowish-brown.
Fusible.
Soluble with gelatinization in hydrochloric acid.

Epidote is mentioned by Monticelli.

Silicates of the Family of Gems.

Zircon—in ejected blocks. Somma.

Chemical composition—silica 34·0, zirconia 66·0.
Crystallization—square prismatic (the crystals often terminated by four-sided pyramids).
Specific gravity—about 4·5.
Hardness—7·5.
Colour—brown; lustre, brilliant. Some small blue crystals in octahedral forms are quoted from Vesuvius by Hausmann.
Infusible.
Insoluble in hydrochloric acid.

Tourmaline—stated by Sir C. Lyell to occur among the volcanic accumulations over Pompeii, and by

Brocchi in lava at Fosso Grande, La Scala, and Torre di Bassano.

Chemical composition (generally)—silica about 38·0, alumina 36·0, boracic acid 8·0, with variable additions of magnesia, lime, soda, potash, and oxides of iron. Fluorine and phosphoric acid are also mentioned, and there is one variety containing lithia.
Crystallization—rhombohedral (in prisms, with three or six terminal planes).
Specific gravity—about 3·2.
Hardness—7·0.
Fusible.
Insoluble in hydrochloric acid.

Serpentine, mixed with chlorite, is given by Monticelli as very rare.

Chrysolite—Peridot, Olivine, Monticellite, for they are supposed to be one species of mineral—occurs plentifully as grains or masses of olivine, externally uncrystalline in form, in ejected blocks, lava, and volcanic ashes.

Chemical composition of a specimen from Somma—silica 40·0, magnesia 44·7, iron protoxide 15·3, with traces of manganese and alumina. Protoxide of nickel is noted in some analyses.
Crystallization (of chrysolite)—rhombic (in tabular forms).
Specific gravity—3·4.
Hardness—7·0.
Colour (olivine)—yellow-green, brown.
Infusible.
Soluble in sulphuric acid, with gelatinization.

Chondrodite—the variety called Humite—is found in ejected blocks with mica. Somma.

Chemical composition (chondrodite)—silica 33·0, magnesia 55·0, iron protoxide 4·0, fluorine 7·0, potash (trace), water (trace).
Crystallization—monoclinic (the forms various).
Specific gravity—3·2.

Hardness—6·5.
Colour (of Humite)—brownish-yellow.
Almost infusible.

Topaz is mentioned by Monticelli on the authority of Bournon and Wollaston, as a product of Somma, in very small crystals.

Titanio Silicates. The two minerals which follow are almost identical in composition, and contain titanium.

Sphene—'Semelina'—occurs in ejected blocks with icespar, &c.

Chemical composition—silica 31·0, titanic acid 42·0, lime 25·0, iron and manganese protoxide 2·0.
Crystallization—monoclinic (tabular crystals, prisms, twin crystals).
Specific gravity—3·5.
Hardness—5·5.
Colour—brown; lustre, brilliant.
Slightly fusible.
Slightly soluble in hydrochloric acid.

Guarinite—in ejected blocks, with prisms of hornblende, peculiar to the Vesuvian tract.

Chemical composition—very much as that of sphene—silica 33·6, titanic acid 33·9, lime 28·0, traces of iron and manganese.
Crystallization—in pyramidal forms.
Specific gravity—3·5.
Hardness—6·5.
Colour—yellow; lustre, brilliant.

In compiling this Catalogue of Vesuvian minerals, the principal authorities consulted are—Monticelli and Covelli, 1825; Scacchi, 1842, &c.; Nicol, 1842; Miller, 1852; Guiscardi, 1855, &c.; St. Claire Deville and Fouquè, in the Ann. de Chimie, passim.

To complete the list of Vesuvian substances we have only to add—

Water, most commonly exhibited as steam; and the following gaseous products:—

Oxygen in atmospheric air.
Nitrogen.
Chlorine.
Hydrochloric acid.
Sulphuric acid.
Hydrogen.
Sulphuretted hydrogen.
Carburetted hydrogen.
Carbonic acid.

The student will find valuable information on the analysis of volcanic minerals in the Revue de Géologie, continued for several years by M. Delesse, M. Laugel, and others.

Some of the rarer minerals of Vesuvius will be found in the collections of the British Museum, arranged by Professor Maskelyne.

On the combination of minerals into rocks, and the classification of these, Cotta's 'Gesteinlehre,' the memoirs of Daubrée (Annales des Mines, &c.),—one of the latest including a classification of rocks,—'Etudes sur le Métamorphisme,' by M. Delesse, and the second edition of Scrope 'On Volcanos,' will be found useful.

CHAPTER XI.

VESUVIAN LAVA AND ASHES.

> 'Quod si quis lapidis miratur fissile robur,
> Cogitet obscuri verissima dicta libelli
> Heraclite tui, nihil insuperabile ab igni,
> Omnia quo rerum naturæ semina jacta.'
>
> *Ætna* (*by* LUCILIUS ?), p. 536.

THE substances composing not Vesuvius only, or volcanic mountains only, but all the Plutonic rocks and minerals which are solid at ordinary temperatures, have formerly been liquid under higher heat, and have been at a still earlier time, perhaps under less pressure, gaseous. In that remote period, in the nebulous condition of our planet, all the elements of its substance, about 64 in number, were separate: during condensation through immeasurable time, many of them have been brought together, one to one, making binary compounds; or two and one, ternary; or two and two, quaternary. But some have remained uncombined; as gold, which is ordinarily solid; others are easily released from combination by moderate heat, as mercury from its combinations with sulphur or oxygen; some submit

to the same divulsion by the application of a high degree of heat, as oxygen from oxide of iron. The chemical history of the earth is written in the solid, liquid, and gaseous matters which compose its mass; the chemical history of volcanos must be recovered by interpreting these records.

If we were able to apply to the rocks and minerals, with their watery and aëriform companions in the crust of the earth, a temperature approaching to, or equal to, or exceeding the point of ebullition of water, we should not for that reason boil away *all* the water in the interstices, crevices, and cavities of rocks; by this augmentation of temperature the solvent power of water, as it is called, would be in general increased, hydrates of various kinds would be formed, and altered combinations might take place in very many rocks and minerals, not only at their surfaces, but in their interior and seemingly impenetrable substance. Minerals, especially zeolitic minerals, might be thus formed in situations where none such were found before. This was ascertained by Daubrée to have happened in the course of the hot waters of Plombières. Now heat in presence of water is one of the conditions of volcanic excitement.

If, further, we conceive of this same zone of mixed substances under the application of heat, amounting to a full red in iron (say 1000° Fahr.), then several metals, as manganese, zinc, iron, tin, cadmium, cobalt, nickel, would decompose the water, and seizing, each, its portion of oxygen, would become oxides.

Under the same conditions, oxides of other metals, as

mercury, silver, gold, platinum, palladium, rhodium, osmium, and iridium, would yield up their oxygen and resume the true metallic state. In this state sublimation would happen to some, as mercury, not to others, as gold.

Under the same conditions, other metals, as arsenic, chromium, vanadium, molybdenum, tungsten, columbium, antimony, uranium, cerium, bismuth, titanium, tellurium, copper, lead, would neither decompose water, nor lose the oxygen from their oxides. Several of these form acids by their union with oxygen. Some of these oxides are volatilizable by heat, as lead oxide.

There is yet another agent of vaporization—hydrogen, which will carry up in combination arsenic, sulphur, and other metals and metalloids. So great a disturbance of equilibrium among the elements of matter is caused by addition or subtraction of heat.

Considered in the same way, the metallic or quasi-metallic bases of the earths and alkalis have points of interest. Several of these bases, as potassium, sodium, lithium, barium, strontium, calcium, attract oxygen from the air at common temperatures, and decompose water, but this is not the case with magnesium, aluminium, glucinium, yttrium, thorium, or zirconium.

So various are the properties of the elementary sorts of matter in the earth: very complex then must be the reactions among them, when exposed to unequal degrees of heat, and to water and air under different temperatures and pressures!

In the list of solid substances we may notice quartz,

analcime, comptonite, and gismondine,—the first for its rare occurrence, as might be expected in lava which contains usually a large proportion of basic silicates; the others on account of their containing water in considerable proportion; thus becoming hydrous silicates. The presence of quartz in its usual characters is of importance in reasoning concerning the origin of granite; the existence of water in the other minerals is quite in accordance with the fact that this liquid is present, even abundantly, in the fluid lava, and capable there of entering into certain combinations of a zeolitic character.

The reader will notice the absence from this list of the beautiful natrolites and chabasites, which occupy cavities in basalt at the Giant's Causeway, and may suppose the reason to be that these substances have been crystallized within cavities of the lava long after its consolidation, not generated in the liquid mass during its consolidation. Comptonite and analcime are, however, found with many other minerals, crystallized in cavities of ancient lava, much as the zeolites of similar character occur in the rocks of the Giant's Causeway and many other tracts of basalt and greenstone. Perhaps if we could examine the submarine parts of the lava-currents which have entered the bay of Naples, we might find in them cavities partly filled by silicates of the order now spoken of. Several metals are absent from the list: notably, gold, silver, tin, nickel; and earths, as glucina, baryta, strontita.

Numerous as are in reality the minerals, and abun-

dant as some are in all the lavas, much disappointment will be felt by collectors not specially versed in the local peculiarities of Somma and Vesuvius. The Vesuvian lava of widely distant epochs is often found to be much alike, usually a mixture of pyroxene, and some basic felspar, with more or less of olivine, sodalite, and leucite; and in this pretty uniform and rather porous aggregate but few other crystals can be found.

One thing rather surprised me on examining Vesuvian lavas, viz. the comparative rarity of genuine felspar of any kind. Instead of this, leucite, sodalite, and haüyne catch attention, and by their union with augite constitute a rock, analogous to, but distinct from, the ordinary greenstone of Plutonic origin. Perhaps the white mineral disseminated in these old rocks is not so often true felspar as may have been supposed.

Some currents of lava are more compactly aggregated, as that of A.D. 1794; and many detached masses thrown out as bombs and found loose among ashes yield a greater variety of crystals. Some large blocks of this kind in the Atrio, and many smaller ones on the vine-covered slopes of Resina, have contributed the rarer minerals, in a beautiful state of crystallization.

There may be reason to regard these freely crystallized masses as having been consolidated under greater pressure and by a slower process than the more rough and porous or cellular surface lavas. They may be fragments torn off from deep-seated rocks, whose situation is in fact Plutonic, and whose definition is 'non-erupted lavas.' They may be compared with the 'dykes'

in Somma, which are unerupted lavas, and yield a greater variety of crystals than the ordinary rocks of that mountain or of Vesuvius.

The lava of Vesuvius is usually granular, rarely cellular, and rough with the prominent angles and edges of small crystals of augite, leucite, olivine, sodalite, &c. It is not trachytic in the sense of being a highly felspathic compound, but, on the contrary, is of the rival or doleritic family, in which hornblendic or augitic minerals with a low per-centage of silica abound. In general its analogue among the Plutonic rocks is 'greenstone.'

It is very rarely so compact as to deserve the title of basalt; nor has this term been often used in describing it. Hamilton mentions that in A.D. 1779 he picked up some 'fragments of large and regular crystals of close-grained lava or basalt, the diameter of which, when the prisms were complete, may have been 8 or 9 inches. They were found on the cone of Vesuvius, and had been thrown out of its crater; and the observer supposed that they had been solidified and shaped within the bowels of the volcano[a].

The lava has often a porphyritic aspect, by reason of the distinctness of the augitic crystals; frequently leucite is prominent in the mass of the old lavas of Somma, as it is also in those of Latium. Olivine gives occasionally a similar sub-porphyritic aspect to the more fine-grained varieties of lava.

[a] Campi Phlegræi. Supplement, p. 4.

As mentioned above, Vesuvian lava is not often cellular; in comparison with the vesicular currents of trachytic lava in Auvergne it may be said to be rarely so. We found it indeed pipy, or full of canals, in particular parts of the currents of March, 1868, on the Pompeian side (p. 121); but it is usually seen to be an aggregate of crystals commonly small and of diverse nature. In the midst of this base are occasional cavities—drusy or lined with crystals of almost every species known in the mountain. But it is in the old lavas of Somma, and in masses previously solidified and in that state ejected, that most of these crystals occur.

It might be supposed that the crystals which line these cavities were not of contemporaneous origin with the rock, but on close inspection it seems otherwise. They are, or appear to be in most cases, as much a component part of the lava, and contemporaneously crystallized with it, as the beautiful quartz, felspar, and mica, prominent in a drusy cavity of Scottish granite, are essential parts of its mass.

Many of the crystals interfere with each other in every way; but it is common to find some, as hornblende, black and brilliant, and sphene or guarinite of a rich brown, imbedded in one or other of the close white spars, while green carbonate of copper lines surfaces, and bright oxide of iron shoots its spangles among scoriaceous lumps.

The composition of lava, as a mass, appears to have been pretty uniform in all the period of Vesuvian activity; if we may judge by the aspect and ordinary

characters. An exact analysis is quite modern. Professor Palmieri records the result of a careful examination, by Professor Silvestri, of Catania, of the more compact part of the lava of A.D. 1867–68 (No. 1). Another analysis (No. 2), by Wedding, of an earlier current, is added (1 Jahresb. v. Kopp. 1839).

	Vesuvius. No. 1.	Vesuvius. No. 2.	Ætna.
Silica	38·888	48·02	51·
Lime	17·698	10·18	10
Alumina	14·127	20.78	19
Protoxide of iron	12·698	Prot. & Perox. 7·97	14
„ of manganese ..	0·010	——	—
Magnesia	3·333	1·16	—
Soda	10·000	3·65	4
Potassa	1·190	7.12	—
Sulphuric acid, Titanic acid, Copper	trace	traces of Chl. Sod. etc.	—
Water	2·063	trace	1

According to Wedding it may be regarded as a compound of leucite 54·0, augite 8·2, meionite 16·3, olivine 5·5, insoluble silicate 8·8, oxydulous iron 5·1, sulphate of lime 0·1, hydroxide of iron 1·2, chloride of sodium 0·8.

The column of parallel results for Ætna shows some important differences, especially in the larger proportion of silica. This is an old analysis by Vauquelin.

A volcanic rock of a peculiar trachytic character, found at Pianura, north of Naples, and much employed for steps, pavements, and purposes requiring massive and durable stone, is called Piperno—not to be con-

founded with the soft Peperino of Rome. It is an ancient lava of the Phlegræan district, and by its unequal composition and almost conglomeritic character has a very different aspect from all the other rocks of the Neapolitan country. The analysis of Dr. Rath and Abich, as reported by Guiscardi [b], yields—

	Piperno.	Val di Bove.	Scarrupata in Ischia.	Drachenfels.
Silica	62·95	62·2	61·74	65·07
Alumina ..	17·26	20·8	19·24	16·13
Protoxide of iron	4·46	4·3	4·12	5·17 Perox.
Lime	0·84	2·7	1·14	2·71
Magnesia ..	0·63	1·4	0·39	6·67
Soda	7·17	5·2	6·68	4·77
Potash	6·06	3·1	5·50	4·44
Chlorine ..	0·65	—	0·19	traces of
Sodium	0·42	—	0·13	water

The column headed Val di Bove shows the analysis, by Plattner, of a felspathic rock in that locality, after removal of the hornblende; the agreement is rather close. The Piperno contains sodalite in crystals. The Ischian rock is almost identical; and all are closely allied to the trachyte of the Drachenfels. Piperno is perhaps one of the oldest of the volcanic products of the Phlegræan tract.

Lava rapidly cooled so as to obscure the crystallization may be expected to be glassy in texture; this, however, is very rarely observable in old Somma, and perhaps never in modern Vesuvius. The only case which has

[b] Rendiconto della R. Accademia delle Scienze Fisiche e Matematiche di Napoli, Agosto, 1867.

been described is that mentioned by Necker; a vertical dyke in the Primo Monte, which overhangs the northern entrance of the Atrio del Cavallo, of a fine leucitic grain, whose sides are glassy for a certain portion of the height. This vitreous band may be called pitchstone, not obsidian, and when inflated with air-cavities it constitutes the pumice of which lapilli are principally composed. Pumice and pitchstone are more plentiful in the Phlegræan fields than in Vesuvius.

The showers of lapilli, ashes, and dust, which make so large a portion of the mass of Vesuvius, may be regarded as disintegrated lava; crystalline grains or dust, separated by the divellent force of the explosion—the force of steam—pervading some parts, perhaps every part of the fluid mass. In some cases lapilli of pumice, in others hornblendic or augitic crystals, of various magnitudes; in other cases scoriaceous masses with leucite, were the elements of the shower of stones and ashes. The diversity of these ingredients corresponds no doubt to a local difference and character of the lava which was dissipated.

Decomposition of lava is effected by the action of air and water, aided by the growth and decay of vegetation. According to the nature of the particular current, its order of silication, the state of its aggregation, and the presence of iron, alumina, soda, potash, magnesia or lime, changes in the mineral constituents are more or less easy. The carbonic acid of the atmosphere, with that derived from decay of plants, operates slowly but effectually in breaking the chemical bond of union among

the elements, and making new arrangements. The iron oxide becomes a hydrate or a carbonate, the alkalis are separated, and the rock is reduced to soil, on which plants operate further changes.

Even on the solid lava, the almost unobserved lichen, itself a sort of living fibre of stone, fixes its unfriendly hold, breaks up the firmest union of grains, and admits the further action of other vegetable growth.

Nor must we omit the supply of gaseous agents, sulphuretted hydrogen, productive of sulphurous acids, and carbonic acid, which is the long-enduring follower of eruptions, and ascends through innumerable fissures, to perform its almost universal work of disintegrating the not everlasting rocks.

Tufa. On these various materials rains and land-floods perform their work, and accumulate muddy deposits, such as probably involved Herculaneum. The same materials, falling into the sea as ashes, or drifted into it by floods, are sorted and distributed by the waves and currents, and constitute strata, more or less regular, according to the character of the watery action. They are *sorted,* and hence the record on our Admiralty charts, of 'cinders' for the soundings on the whole coast from near Naples to near Pompeii, while farther out in deeper water, gravel, sand, mud, and clay are found. As the strong wind scatters fine volcanic dust over distant lands, the agitated water distributes fine materials of the same origin over far-removed parts of the bed of the sea.

The deepest part of the crater, as the whole bay of

Naples may still be called, is on the line from Ischia to Capri, nearer to the former island, 328 fathoms (1968 feet), and the soundings are 'sand.' So are they at a point on the same line nearer to Capri, 207 fathoms (1242 feet) deep; but almost everywhere else in this large bay, and round the Cumæan coasts, mud prevails till we approach the shore. The sea-bed slopes at a small angle, 1°, 2°, or 3°, so that below its waters is a sub-Vesuvian stratified deposit, comparable to the older sub-Apennine, and, like it, to be raised perhaps into fertile land.

The sub-aqueous origin of the volcanic tufa, which is expanded in Campania, appears to have been generally admitted, and indeed can in no manner be doubted. The materials of the mass are of igneous, the structure of watery origin. Professor Forbes describes the layers of the tufa of Pausilippo as succeeding each other with great regularity and sharpness. They are composed of various alternating volcanic conglomerates, granular tufa, and pebbly and pumiceous bands, firm or friable, but all irregularly stratified. The stratification is by no means uniform; lenticular curves, and parallel laminæ, both inclined and horizontal, occur in seeming confusion, but all in harmony with the idea of deposits under often troubled undulation of shallow water.

In the hill of Pausilippo these varying structures are remarkably well exhibited, both on the westward and eastward sides: the most prevalent dip is south-eastward.

In the sketch on p. 314 the lines mostly represent layers

of lapilli and ashes: nearly the whole is traversed by finer layers of the sort. The lapilli lie often in streams with a lenticular section (*l*), ten or more yards long. They consist of pumice, pitchstone, and cellular lava, in general not rounded, but in some layers they are all rounded. The thickest layers are from 1 foot to 1 foot 6 inches. Some examples occur of hollows in the tufa, which are filled up by horizontal layers of ashes, 6 or 8 feet deep (*h*).

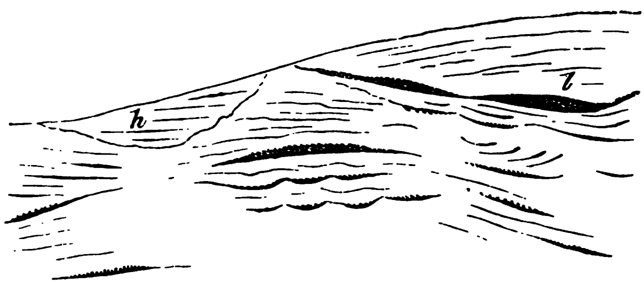


Diagram XXXV. SECTION OF TUFA, PAUSILIPPO.

The *fact* of these strata being really deposited and arranged under water is made evident by the discovery at Pausilippo, by Sir W. Hamilton and since by other observers, of marine shells, of existing species imbedded in the tufa. Among these are large examples of the common oyster, exactly such as now live in the neighbouring sea. This tufa forms the range above Pausilippo, and attains its full height in the Camaldoli, which is 1513 English feet according to Forbes, and 1502 feet according to the Admiralty Chart of A.D. 1857.

To determine the origin of lava is to settle the basis of volcanic chemistry, and go far toward completing the theory of volcanos. To one standing by the current as it rushes red from its reservoir, a strong but variable stream, nothing seems so obvious as the conclusion that it springs reluctant from an unfailing source, under the pressure of an elastic agent. Now rising into sudden jets, then sinking into a difficult outflow; subject even to some sort of periodicity, or process analogous to that of a forcing-pump, it is evidently compelled to yield to a power which, if not capricious, is itself governed by some natural law of growth into energy, followed by the exhaustion of effort. Such a power is steam, and such a law masters its might. Water admitted to a subterranean basin of liquid rock, appears to his mind sufficient for the mechanical theory of volcanic action: he sees the active volcanos of all the world situated near ample surfaces of sea or lake, and finds the volcanos which are now extinct to have been surrounded or margined by such waters, at the time when they were active.

When he finds that neighbouring volcanos sympathize or reciprocate in their efforts, or comes to learn that a kind of universal tremor with frequent eruptions terrifies half the globe,—as in this very year,—he draws from this a conviction that the deep-seated basins of lava have some underground connection, and that they may all be influenced by recurring general conditions which bring into action the local violence of steam-power.

If asked what is the depth of this lava-flood, he replies that its source must be deeper than the focus of earthquakes, because these vibrations are propagated in solid rocks, and their depth under the mountains of South Italy is about eight miles. How it happens that water can pass down to this depth he may not have considered with critical attention, but that it does pass down in large quantity is evident by the enormous volumes of cloud which gather at intervals over volcanic vents, and perhaps may be supported by the known disturbances of the sea-level, first by retreat, and then by violent return of destructive waves to break on the volcanic shore. For by fracture of the sea-bed, water might be admitted to an interior cavity, and both earth-waves and water-waves generated: the former reaching the land first and raising it while passing, would repel the sea, which afterwards would return with accumulated force. This difficulty—the access of water to the deep-seated fluid rock—must be met by every theory, and is not therefore fatal to any.

To questions regarding the peculiar mineral character of the lava, his reply is an immediate appeal to very similar products which have appeared under conditions more or less alike in all geological periods, and still appear in all volcanic districts. This lava is part of the interior unsolidified mass of the earth, and our globe is one of many great masses which have the same or similar mineral constitution. Further explanation, if it be needed, must be sought in the history of the

aggregation of the matter of our planet, and the separation of our satellite.

With this mode of viewing the subject, a fluid basin of rock, to which water has access, no difficulty occurs in admitting the formation of hydroxides and hydrosilicates; or of cavities within which they might be specially frequent; or of the bursts of steam 'globes' from the upper parts of the lava-current; nor if the volcano be near the sea, as Vesuvius is, need we be surprised to find chlorides of sodium and chlorides of metals among the ordinary products of sublimation.

What, then, can seriously be urged against this which seems so natural and so plausible an explanation of the origin of lava and the phænomena which accompany and follow it to the surface? Perhaps the presence of nitrogen among the products of Vesuvius may be thought to be the circumstance least favourable to the reception of the hypothesis we are considering. This element is observed sometimes in the chloridic compound called sal ammoniac, as well as in the free gaseous form. Ammonia is formed by the union of nitrogen and hydrogen. Whence came these elements? Perhaps by the downward passage of air nitrogen was conveyed, and by the decomposition of water 'nascent' hydrogen appeared, and these gases might combine under pressure. But how is the water decomposed? By oxidation of some basis, as sodium, or raising the degree of oxidation of some substance like oxide of iron, or some decomposable organic bodies, fossil plants or animals. Steam passed over a mixture of common salt

with silica or alumina, at a high temperature, is decomposed, its hydrogen going to the chlorine, its oxygen to the alkaline basis. Here then we have chlorine, hydrogen, and nitrogen in presence, at high temperature, under great pressure. May not $N\,H^4\,Ch$ = sal ammoniac result? Again, why may not nitrogen and hydrogen, alone or combined with other elements, and sulphurous acid and carbonic acid, be evolved from the organic products which abound in many of the strata traversed by volcanos? All hot springs were found by Daubeny to yield nitrogen, and this is explicable by the absorption of oxygen during the 'eremacausis' of animal and vegetable matters, which are bathed by water and air in its passage through rocks, whether in a volcanic region or not, which share in the warmth of the earth. Davy found the air which came up through the fissures of heated lava to be poor in oxygen; it was atmospheric air circulating through crevices of the rocks, and may have supplied the means of converting the protoxides of iron, which are commonly combined with silica in all lava, into the sesquioxides, which occur frequently, and not in small quantity, separate in the fissures.

One man indeed, the great discoverer of the metallic bases of the earths and alkalies, while standing by the current which was flowing in the winter of A.D. 1819–20, allowed his thoughts to travel backward to the origin of rocks, and to apply to the chemical phænomena of Vesuvius the laws of combination which he had discovered in the laboratory of the Royal Institution.

It was in A.D 1812[c], in his paper on the Decomposition of the Earths, that Davy first offered it as a conjecture that the metals of the alkalies and earths might exist in the interior of the globe, and on being exposed to the action of air and water give rise to volcanic fire and the production of lava; by the slow cooling of which basaltic and other crystalline rocks might subsequently be formed. He repeated this conjecture, as already stated, a few years later, while examining the chemical peculiarities of the eruption, but he concluded by acknowledging that the hypothesis of the nucleus of the globe being composed of matter liquified by heat offers a still more simple solution of the phænomena of volcanic fires.

The hypothesis thus practically abandoned by its brilliant author found a steady and persevering supporter in Dr. Daubeny, in whose treatise on Volcanos it was advocated under the title of 'The Chemical Theory of Volcanos.' With great ability the Oxford Professor maintained the speculation of Davy, by special chemical arguments, which appeared to show that the observed products of an eruption were of the kind to be expected from 'oxidation of the metallic bases of the earths and alkalies' through the agency of water and atmospheric air, and that these products appeared in the order which the theory required.

This appears to be true, but it is not proved that the same effects might not equally happen on the suppo-

[c] Phil. Trans. for 1812 and 1828. See also Abstracts of the Phil. Trans. vol. ii. p. 338.

sition that water and air were brought into contact with rocks already fluid, and that the heat of the globe would effect changes in stratified deposits containing organic remains. Moreover, two great objections arise against the views of Dr. Daubeny. If water be decomposed and its oxygen fixed in combination with lava, what has become of the released hydrogen? No doubt a small quantity appears combined with sulphur; some is fixed in sal ammoniac; and some is thought to be free. But there ought to be not small quantities but very many millions of cubic feet of unmistakable free hydrogen, in an immense blaze above the mountain.

Again, if water be decomposed to make the lava and maintain the heat, how do we supply such vast volumes of uprushing steam, and infer the presence of more in underground cavities, to balance the weight of the columns of lava? No doubt it may be said that water enters the volcano in very large quantity, and that it is only partly decomposed; but such an admission only shows that a very limited chemical action is really required, the main governing force being dependent on the heated interior of the globe.

Among recent additions to our chemical knowledge of volcanic phænomena, not indeed derived from Vesuvius, but from the eruptions of Ætna in A.D. 1865, must be mentioned the Report of M. Fouqué, to the French Academy. After careful study of the products of eruption, in the order of their appearance, and especially of the gaseous products—agreeing in this generally with the researches of St. Claire Deville in Vesuvius—

M. Fouqué has convinced himself that the chemical reactions which are traced in volcanic phænomena are effects, not causes, of the eruptive process. He is satisfied that it is not to chemical reactions among the particles of matter—oxidations of metals and the like—but to the simple action of infiltrated water on a hot interior bed of fluid rock. Among other interesting results, he reports the sublimation, at high temperature, of carbonate of soda, carbonate of ammonia, and bicarburetted hydrogen; these and other substances being all volatilized together, but not all continuing to appear together as the temperature becomes lower.

CHAPTER XII.

GENERAL VIEWS LEADING TO A THEORY OF VOLCANIC EXCITEMENT.

'Nec tellus obstat, quin omnia despiciantur,
Sub pedibus quæcumque infra per inane geruntur.'

LUCRETIUS.

In whatever degree the inquiries opened in the preceding chapters have enabled us to perceive the true order and dependence of the successive phænomena of an eruption of Mount Vesuvius, in the same degree we have been advanced toward a right conception of the theory of volcanic action. In questions of this kind, conclusions founded on true views in a limited region may become general truths, by just combination with others having a similar origin in other situations; and thus, step by step, sure inductive processes may lead us up to the highest and clearest knowledge of which the subject admits.

The theory of volcanos has been approached from various points of view; but not fully reached by any one of the roads. It is something, however, to have

discovered roads to this subterranean fortress of nature, for such were not known to our forefathers. The popular creed of the thunder-stricken Titan, stretched helpless and hopeless beneath the load of Ætna; the fiery workshops of Hephaistos; the struggling winds of the Æolian caverns, were as good explanations as the fires of sulphur and bitumen which, in the middle ages, took the place of the grand old legend. In modern times it is agreed to treat volcanic phænomena as local effects depending on some general conditions: if we find out these conditions, we have made some real progress on the way to the discovery of the theory. Some of the conditions are certainly general, and occasion general conformity of results; yet the local effects are certainly diverse, and this diversity can only be caused by special differences of condition.

Obsidian, a highly silicated lava, abounds in Teneriffe and the Mexican volcanos; pyroxenic currents flow from Vesuvius, with a far lower per-centage of silica. Trachyte alone forms mountains which are not crateriform in Auvergne; ashes and basaltic lavas compose other mountains in Italy and Iceland. Some mountains, as Stromboli, are now constantly active, and have been so in all the reach of history; while others have long intervals of rest, and some have sunk to a quiet sleep, like a peaceful death in nature.

What are the general conditions, what are the causes of particular diversity? This is the problem on which we are intent.

Two objects of inquiry are before us: one includes

the phænomena which any particular volcano exhibits in its actual eruptions, and in the remaining monuments and effects of former disturbances, by which we may learn to characterize the particular kind of action which we call volcanic, and to refer it to real though limited causes; the other embraces a conspectus of such phænomena, by which to learn their mutual dependence or relationship, in time, space, force, and general terrestrial or cosmical conditions. We must in this large sense extend our observations to the sun and the moon, the planets and the nebulæ; for a complete theory of volcanos should contain a real account of the consolidation of matter, and be in harmony with the general history of the cosmos.

An interior fluid composed of silicated earths, alkalies and metals, accessible to water, and open, or capable of being opened, to the air or the ocean, is the fundamental condition of volcanic excitement. That this fluidity is due to the inherent heat of the globe, may be regarded as a settled point: what is known regarding this heat, its depth, intensity, variability and origin? what are its effects in the economy of nature? If we can answer these questions on sure grounds of evidence, we shall have gone far to connect the history of Vesuvius with that of the globe we inhabit.

The earth receives annually a nearly constant supply of radiant heat from the sun: it loses annually a nearly constant measure of heat by radiation into the cold spaces which surround the planets and stars: these opposite effects are so nearly balanced that on the average

of years the surface of the globe, taken as a whole, remains of the same temperature, and the variations of climate at any particular point of the surface are small.

At any particular point of the surface the temperature varies from the average of the whole earth in a certain relation to latitude,—for in proportion to latitude is the quantity of sunshine which falls on a given area. This relation on the average is pretty accurately expressed by the cosines of latitude [a].

Again, places elevated in the same latitude above the level of the sea, and raised into the atmosphere, are cooled by their position; not in the simple proportion of the height, but nearly so at small elevations, so that for every 100 yards the mean temperature sinks about 1° Fahr.

The sea in high latitudes is warmer than the air in winter, cooler than the air in summer, and thus it happens that circumpolar islands and sea-coasts have a milder climate than continents. This is especially the case on the western coasts and islands of Europe; in a less degree it applies to the western coasts of North America. These coasts and islands are somewhat warmer than the average of the latitude, by reason of sea-currents and warm winds from the south-west.

The atmosphere has on the whole more the effect of diminishing the waste of heat from the earth, by radiation into space, than of checking the heat-rays

[a] Thus let 80·0 be the mean temperature of the equator, and it be required to assign the mean temperature of a point in North Lat. 50°. The calculation is thus made: 80·0 × cosine of Lat. = 51·4°.

which come from the sun. In early geological times this effect of the atmosphere, then greater in extent, more loaded with vapour, and more mixed with carbonic acid gas, was probably greater than it is now.

By duly considering the circumstances enumerated, both the general conformity and the particular diversity of climates may be well understood for most points on the surface of our planet.

Thus it appears that whatever be the degree of heat of the globe, internally, this heat has no very obvious effect on the temperature of the surface; and this result would not be much altered if the degree of internal heat were greatly different from what it is, because of the feeble conducting power of the rocky crust of the globe. There would be some alteration of temperature, however, produced at the surface, by a change of the heat of the interior, or the nearer approach of that heat to the surface; and the law of alteration is actually known by experiments, both at small and at considerable depths.

The warmth of day and the coolness of night, summer heat and winter cold, penetrate the ground in succession; as we descend the variations caused from these changes grow less and less, and grow later and later. At 24 French feet in depth the heat of Midsummer is felt at Christmas, and at twice that depth the heat of one summer is felt a year after date. As the depth increases the variations diminish in amount. At the surface in England about 26° is the average difference of mean temperature between summer and winter; at

60 or 80 feet it is entirely insensible. Whatever be the temperature of the earth below that point, it must be due entirely to circumstances peculiar to the origin of the earth, (chaleur d'origine,) or to some cosmical conditions distinct from what are now occurring in our daily rotation and annual revolution.

Strong springs that issue continually from rocks or gravel-banks, and bring with them the temperature of the ground at small depths, are found to be of the same temperature as the air on an average of the year: if they come from a considerable depth, as from a deep well, they are warmer than the average of the air, and if from a great depth much warmer. By frequent trials it is found, in many parts of Europe, that the temperature of water issuing under these circumstances rises 1° Fahr. for every 50 feet of descent, sometimes 1° in 45 feet, and again 1° in 60°. Applying this scale to the water of Bath, which issues in abundance at 110°—the mean annual temperature of the city being 50°—we have $60° \times 50 = 3000$ feet for the depth in the earth represented by the temperature of the spring. In some countries, not volcanic, springs occur at 180°, and at boiling temperature 212°: this last temperature would be found, it is probable, under London at about $162° \times 50 = 8100$ feet, somewhat above 1½ mile.

Another set of experiments made in the mines of Cornwall, France, Germany, &c., gives a similar result; viz. 1° Fahr. augmented temperature for 45 feet of depth, and a third set, in the collieries of England, concurs with the other in general meaning, but shows

a less rate of increase, viz. 1° in 60 feet. At this rate the heat of boiling water would be found under London at $162° \times 60 = 9720 = 1\frac{3}{4}$ mile.

The temperatures at these various depths are kept practically constant, even amidst the varying circumstances of mines and collieries, by the perpetual gentle flow of heat upwards, from the interior. The effect of this flow is continually to warm these rocks and the surface a little. The amount of this heating at the surface has been estimated at $\frac{1}{20}$ of a centigrade degree. Another estimate is that the quantity of heat which thus passes out from the earth, in one year, would melt a sheet of ice one quarter of an inch in thickness[b].

Such is the state of our knowledge on this curious subject of inquiry: and if this were all it would amply justify, and indeed compel the belief, that for depths far greater than a mile or ten miles, the heat would be found to go on increasing in nearly the same ratio if the rocky crust of the earth be of the same quality in regard to heat; that is to say, would conduct heat in the same manner and degree. Now we know this crust to be of the quality required for 5 or 10 miles at least in certain countries, as for example England; but in some other parts of the earth, as Northern Canada, 20 miles would not be thought too great an estimate[c].

[b] See in the Appendix an interesting letter on this subject, with accurate results, by Principal Forbes.

[c] See Sir W. Logan's Memoirs, which accompany his admirable Survey of Canada. Professor Ramsay reckons 14 miles for the British strata, each taken at its full thickness.

At this depth (20 miles) we should have a temperature of about 2000°, more or less, according to our choice of 40, 50, or 60 feet for the augmentation of temperature 1.

Now at this temperature a great portion of our rocks and metals, taken singly, would be in fusion; still more easy would be their fusion in a mixture; just as in Pattison's refining process the mixed silver and lead are retained in a liquid state at a degree of heat much below that which is required to melt the lead, and allowed to cool by degrees till the lead crystallizes out of the mass, and falls by its superior weight to the bottom of the iron vessel.

To admit the reality of an interior fluid is the natural result of correct reasoning on the distribution of heat in the exterior solid coating of our planet. It may be objected no doubt that 'pressure may raise the temperature of fusion,' and so prevent liquidity; but if this be well considered it will certainly appear that, according to all analogy, pressure must rise in a higher ratio than the temperature, in order to produce solidification; and as it is certain that both temperature and pressure rise alike in arithmetical progression (at such depths as we are now considering), it is most probable that liquefaction can only be prevented in a slight degree by pressure; very possibly it is not prevented at all.

To reason, as some geologists have done, that from the centre of the earth solidification may have spread itself to the circumference, is very little to the purpose, since it is obvious that in every successive zone the pressure

would diminish, while the temperature would rise, by reason of the exchange of conditions from a liquid to a solid state. A solid central mass may be compatible with a consolidated crust; but if the phænomena indicate, as we have seen they do, fluidity of rock at no great depth, there is no argument to be founded on central solidity which can prevail against the conclusion, which seems obvious, that beneath our feet, at a depth not too great to influence geological phænomena, the substance of the globe is fluid with heat.

There is, however, an inquiry to be made—how far the true condition of the interior of the earth is indicated by any astronomical phænomena in which that condition is an element of influence. One such is known, and has been thoroughly explored by a competent hand—the late excellent mathematical reasoner, Mr. W. Hopkins of Cambridge. The precession of the equinoxes (with its accompanying inequality called the nutation) depends on the equatorial protuberance of the terrestrial spheroid; acting on it, the attraction of the sun, and in a greater degree the moon, causes the earth's axis to point to different parts of the heavens and describe a circle therein of 47°—itself being all the while inclined equally or nearly so to the orbit of revolution. The rate of progress is 50″ of angle in a year, and in about 25,800 years the circle is completed.

Now this rate would not be the same for a solid spheroid, as for a spheroid only solid near the surface, unless the interior fluid were truly spherical. There is every reason to believe that in a globe grown partly

solid while rotating on its axis, the residuary internal fluid could not be spherical; in other words, the inner as well as the outer surface of the earth's crust or shell must be spheroidal, and have the degree of ellipticity due to its position and velocity of rotation. Under this condition an internal freely-flowing liquid would not yield to the attraction of the sun and moon in the same degree as the solid crust, but much more easily, and the annual amount of the precession would be considerably different from what it is.

This being granted, it follows that to a certain depth at least, including the most effective parts of the spheroidal shells—most effective in the sense we are considering—the earth must be solid. The depth of solidity, it appears from Mr. Hopkins's problem, ought to be, say one-fourth of the radius of the earth, including therefore more than half the volume of the earth. 600 or 800 miles is the least depth that he can allow for solidity. Can any one believe that lava is pressed up through channels of that length?

It is not in the least degree necessary that he should, nor did Mr. Hopkins desire it. When we come to consider the meaning of the solution which he presents, it is this:—There must be such a condition really existing below the surface that there must be no difference, or a very small one, in the degree of yielding to the attraction of the sun and moon (until a great depth is reached). This condition may be secured, as Mr. Hopkins himself thought, by the existence of separate liquid basins (as under separate volcanos), so confined within

solids as to compel them to yield as a mass in sympathy with the solid crust. Such a state of things is in no degree unlikely, and it leaves the geologist quite free to adopt any suitable depth for lava, without fear of the mathematician.

But this is not all. There is a fundamental objection, not to the mathematical formula, but to the condition assumed in it of free-flowing liquid rock. The interior fluid can only be of the nature of lava, and that when examined at the surface, however fresh, is a very intractable mass, flowing indeed, as does thick honey, pitch, or slag; incapable of moving at the very utmost above a few miles an hour, even on a slope of 30°, and on ordinary slopes only one mile, half a mile, or even 30 or 40 feet in 60 minutes. To such a slow reluctant fluid the computation suited for a pure liquid has really no application; and it is not necessary to make any correction for its 'friction' against the inner surface of the shell, or its unequal yielding to the precessional force which acts on the solid crust of the earth. The problem, solved by Mr. Hopkins, looked at in this light, does really not settle anything as to the thickness of the crust of the earth; and to this conclusion it is understood M. Delaunay has been lately conducted both by strict reasoning and experiment.

The globe is continually, though very slowly, losing heat, it grows colder in a very small degree, and suffers contraction in the same small degree. It appears that since the days of Hipparchus, about 2000 years have passed without any change being observed in the length

of the day, and this is sometimes urged as a reason for not accepting the explanation of the depression of seas and the rising of mountains which geologists have founded on the 'refrigeration of the earth.' But it only proves, what is quite well known from other considerations, that the process is very slow.

The globe then is suffering contraction: it is smaller than it was: but if this were all, no important geological explanations could be made to depend on it. If *the whole globe* were to undergo contraction by loss of heat at the rate of the red granite of Peterhead[d], viz. $\frac{1}{2000000}$ of a unit of length for each 1° of Fahrenheit, the diameter would change for each degree, say $\frac{7914}{2000000}$, about $\frac{1}{25}$ of a mile (209 feet). The alteration of the length of the day due to such a general change of dimensions would be about four-tenths of a second of time. 209 feet of change of radius in a globe of uniform composition would produce no sensible effect on the phænomena of elevation and depression on the surface of the earth; nor any important effect on such a globe, partly dry and partly covered by water. But in a globe subject to unequal expansion or contraction of the mass, as our semi-fluid earth must be, the effect of even one degree of cooling could not be otherwise than very effective in producing geological change.

It must not be thought for a moment that reduction of temperature has ever been or ever can be accomplished

[d] See on questions of this order, and generally on the effect of refrigeration of the globe, the Ninth Bridgewater Treatise of Mr. Babbage.

at a uniform rate through all the mass of the globe. At the epoch of solidification of the surface, with a temperature of about 2058°, isothermal zones began below the surface; as time passed on they descended lower and lower; so that at present the temperature of 2058° may be found at about twenty miles, while the surface heat is about 58°. The surface has been cooled 2000°; at five miles in depth 1500°; at ten miles 1000°; at twenty miles 0°.

From this it will be evident that pressures on a great scale, to match the contraction, must have been occasioned in all past geological time, until the temperature of the surface became fixed or nearly so, as we find it. In the earlier parts of the period, the pressure must have been greatest at the surface, where the contraction was the greatest. But it is not so now. This tendency to contract may be regarded as ended at the surface, where the isothermal is constant or nearly so: it is still effective in the deeper parts, where the isothermals are slowly descending toward the surface of growing consolidation; and the production of fissures there, though on a small scale, must be the natural consequence of the changes of relative dimensions and tensions still going on.

From what we certainly know of the constitution of the crust of the globe, it is of unequal strength to resist change of form in different parts. The weakest part must yield, and if by local yielding the general pressure may be satisfied (which is equivalent to supposing the general pressure determined to a small area), the dis-

placement of a small tract may be extremely great, and the rocks there be bent into arches, or broken by faults. If we are right in our views of the history of the globe, very many epochs would arise, when, first in one region, then in another, lines or areas of relative weakness would be depressed into concave seas, and receive a long series of deposits; and at other times the same areas or parts of them might be relevated, producing end-pressures and violent local flexures or fractures.

Whoever considers this with attention, will perceive that De Beaumont's hypothesis of mountain elevation by contraction of the globe must have some features of local truth; though its general application, with geometrical symmetry, and through parallel lines of great circle fractures, may not be accepted.

One phænomenon remains for consideration. The mode in which the earth grows solid is by separation of parts which concrete from the general mass of fluid. In an early stage of my geological studies, I was much impressed by a fact which is extremely frequent, viz. the anteriority of granite to greenstone, and of felspathic or highly silicated rocks in general to hornblendic or basic silicates. Felspathic silicates are in general less fusible than the hornblendic rocks, and there can be little doubt that they crystallized out of the mass of cooling liquid, and separated from the more fusible portions.

Moreover, these felspathic silicates are lighter specifically than the hornblendic rocks, in the proportion of 2·6 to 3·2; and on this hangs an important inference.

Being relatively lighter, they would when solid rise in the liquid, and exert a positive pressure upwards on the superincumbent earth-crust, and tend to elevate the region. At this time it is affirmed by Lyell, that the northern part of Scandinavia is rising at the rate of 30 inches in a century. The formation of less than 14 feet of granite in one hundred years by crystallization under this region would be enough to account for the elevation which is observed.

To me it appears clear that on the general fact of a cooling globe, two great systems of movement in the earth's crust are to be surely inferred; one downward, by reason of the determining of a general contraction to particular axes and centres; the other upward, arising from the crystallization of rocks whose specific gravity is less than that of the whole mass. Whether these rocks entangle themselves below, so as to constitute practically a solid basis, or float in a magma of slow fluidity, is of no material consequence to the general theory of the earth, or to the particular theory of volcanos. The conformity and the diversity of these latter can be well enough explained either way; conformity of general phænomena from causes of like origin, diversity of particular effects from the varying depths and communications of the channels, and the different qualities of the solid rocks which are rent by earthquakes, absorbed by heat, and ejected by steam.

Here then we pause; not without a conviction that geology is acquiring, even with reference to the variable might of subterranean fire, a sure ground of conviction

that it is a part of the system of slow and measured change which has been traced in operation, through the members of the solar system and the starry spaces beyond, to the greater and more distant masses of shining vapour, which, though they stand to us, at present, as the 'flammantia mœnia mundi,' may even now be silently gathering into new suns, and planets, and satellites; or forming elliptic rings of asteroids, such as were seen on this morning of the 14th of November 1868, by the author, at Oxford.

POSTSCRIPT.

IN the English journals of Dec. 12, 1868, appears the following notice:—

Ætna and Vesuvius.—Professor Palmieri, of Naples, has communicated the following relation to the journals of that city:—'The cooling of the lava of Vesuvius having been the signal for an eruption of Ætna, many persons will probably desire to know what the former is doing while Mongibello is on fire. These two volcanos, which have nearly always existed independent, appear lately to have established some sort of unison. On the night of the 26th of November, the last current of molten fluid descended from the first-named mountain, and

on the 27th a majestic and dazzling crest appeared on the Sicilian one. The ten cones of eruption of Vesuvius instantly lost their frightful activity; but the small crater which had been formed about half-way up the great cone still emits much smoke; at night there are luminous reflections. The summit of the elevation, where the small cone of 1868 was situated, has disappeared, and that of 1867, which has lowered considerably, still allows much smoke to escape, accompanied by some noise. The heat is intense in all the higher steaming crevices.'

APPENDIX.

TYPHON.

(pp. 2, 230.)

Homer has these lines (Iliad B. l. 780), which mention Ἀριμή as the bed of the Titan :—

> Οἱ δ' ἄρ' ἴσαν ὡσεί τε πυρὶ χθὼν πᾶσα νέμοιτο·
> γαῖα δ' ὑπεστενάχιζε Διὶ ὣς τερπικεραύνῳ
> χωομένῳ, ὅτε τ' ἀμφὶ Τυφωέϊ γαῖαν ἱμάσσῃ
> εἰν Ἀρίμοις, ὅθι φασὶ Τυφωέος ἔμμεναι εὐνάς.

Pindar, in the first Pythian Ode (l. 33), buries this huge type of volcanic fire under the vast space stretching from Cumæ to Sicily :—

> νῦν γε μὰν
> ταί θ' ὑπὲρ Κύμας ἁλιερκέες ὄχθαι
> Σικελία τ' αὐτοῦ πιέζει
> στέρνα λαχνάεντα.

Æschylus makes Prometheus (l. 363) say of Typhon :—

> καὶ νῦν ἀχρεῖον καὶ παρήορον δέμας
> κεῖται στενωποῦ πλησίον θαλασσίου
> ἰπούμενος ῥίζαισιν Αἰτναίαις ὕπο.

STRABO.

(pp. 5, 29, 209.)

The following passage relates to the Solfatara :—

Ὑπέρκειται δὲ τῆς πόλεως εὐθύς, ἡ τοῦ Ἡφαίστου ἀγορά, πεδίον περικεκλεισμένον διαπύροις ὀφρύσι, καμνώδεις ἐχούσαις ἀναπνοὰς πολλαχοῦ, καὶ βρομώδεις ἱκανῶς· τὸ δὲ πεδίον θείου πλῆρές ἐστι συρτοῦ.

Neapolis is thus described :—

Μετὰ δὲ Δικαιαρχίαν ἐστὶ Νεάπολις Κυμαίων· ὕστερον δὲ καὶ Χαλκιδεῖς ἐπῴκησαν, καὶ Πιθηκουσαίων τινές, καὶ Ἀθηναίων, ὥστε καὶ Νεάπολις ἐκλήθη διὰ τοῦτο, ὅπου δείκνυται μνῆμα τῶν Σειρήνων μιᾶς Παρθενόπης, καὶ ἀγὼν συντελεῖται γυμνικὸς κατὰ μαντείαν. Ὕστερον δὲ Καμπανῶν τινας ἐδέξαντο συνοίκους διχοστατήσαντες· καὶ ἠναγκάσθησαν τοῖς ἐχθίστοις, ὡς οἰκειοτάτοις χρήσασθαι, ἐπειδὴ τοὺς οἰκείους ἀλλοτρίους ἔσχον. Μηνύει δὲ τὰ τῶν δημάρχων ὀνόματα, τὰ μὲν πρῶτα Ἑλληνικὰ ὄντα, τὰ δ' ὕστερα τοῖς Ἑλληνικοῖς ἀναμὶξ τὰ Καμπανικά. Πλεῖστα δ' ἴχνη τῆς Ἑλληνικῆς ἀγωγῆς ἐνταῦθα σώζεται, γυμνάσιά τε καὶ ἐφηβεῖα καὶ φρατρία καὶ ὀνόματα Ἑλληνικὰ καίπερ ὄντων Ῥωμαίων. Νυνὶ δὲ πεντετηρικὸς ἱερὸς ἀγὼν συντελεῖται παρ' αὐτοῖς, μουσικός τε καὶ γυμνικὸς ἐπὶ πλείους ἡμέρας, ἐνάμιλλος τοῖς ἐπιφανεστάτοις τῶν κατὰ τὴν Ἑλλάδα.

The Grotto or Tunnel on the road to Pozzuoli is noticed, and the hot springs :—

Ἔστι δὲ καὶ ἐνθάδε διώρυξ κρυπτὴ τοῦ μεταξὺ ὄρους, τῆς τε Δικαιαρχίας καὶ τῆς Νεαπόλεως, ὑπεργασθέντος ὁμοίως, ὥσπερ ἐπὶ τὴν Κύμην, ὁδοῦ τε ἀνοιχθείσης ἐναντίοις ζεύγεσι πορευτῆς ἐπὶ πολλοὺς σταδίους· τὰ δὲ φῶτα ἐκ τῆς ἐπιφανείας τοῦ ὄρους, πολλαχόθεν ἐκκοπεισῶν θυρίδων, διὰ βάθους πολλοῦ κατάγεται. Ἔχει δὲ καὶ ἡ Νεάπολις θερμῶν ὑδάτων ἐκβολάς, καὶ κατασκευὰς

λουτρῶν οὐ χείρους τῶν ἐν Βαΐαις· πολὺ δὲ τῷ πλήθει λειπομένας· ἐκεῖ γὰρ ἄλλη πόλις γίνεται, συνῳκοδομουμένων βασιλείων ἄλλων ἐπ' ἄλλοις οὐκ ἐλάττων τῆς Δικαιαρχίας.

The manner of life at Neapolis:—

Ἐπιτείνουσι δὲ τὴν ἐν Νεαπόλει διαγωγὴν τὴν Ἑλληνικήν, οἱ ἐκ τῆς Ῥώμης ἀναχωροῦντες δεῦρο, ἡσυχίας χάριν τῶν ἀπὸ παιδείας ἐργασαμένων, ἢ καὶ ἄλλως, διὰ γῆρας ἢ ἀσθένειαν ποθούντων ἐν ἀνέσει ζῆν· καὶ τῶν Ῥωμαίων δ' ἔνιοι χαίροντες τῷ βίῳ τούτῳ, θεωροῦντες τὸ πλῆθος τῶν ἀπὸ τῆς αὐτῆς ἀγωγῆς ἐπιδημούντων ἀνδρῶν, ἄσμενοι φιλοχωροῦσι καὶ ζῶσιν αὐτόθι.

Herculaneum and Pompeii are described:—

Ἐχόμενον δὲ φρούριον ἐστὶν Ἡράκλειον, ἐκκειμένην εἰς τὴν θάλασσαν ἄκραν ἔχον, καταπνεομένην Λιβὶ θαυμαστῶς, ὥσθ' ὑγιεινὴν ποιεῖν τὴν κατοικίαν. Ὄσκοι δὲ εἶχον καὶ ταύτην, καὶ τὴν ἐφεξῆς Πομπεῖαν· ἣν παραρρεῖ ὁ Σάρνος ποταμός· εἶτα Τυρρηνοὶ καὶ Πελασγοί. μετα-ταῦτα δὲ Σαννῖται· καὶ οὗτοι δ' ἐξέπεσον ἐκ τῶν τόπων. Νώλης δὲ καὶ Νουκερίας καὶ Ἀχέρων, ὁμωνύμου κατοικίας τῆς περὶ Κρεμώνα, ἐπίνειόν ἐστιν ἡ Πομπεΐα, παρὰ τῷ Σάρνῳ ποταμῷ καὶ δεχομένῳ τὰ φορτία καὶ ἐκπέμποντι.

Vesuvius and the indications of fire:—

Ὑπέρκειται δὲ τῶν τόπων τούτων ὄρος τὸ Οὐεσσούϊον, ἀγροῖς περιοικούμενον παγκάλοις, πλὴν τῆς κορυφῆς· αὕτη δ' ἐπίπεδος μὲν πολὺ μέρος ἐστίν· ἄκαρπος δ' ὅλη· ἐκ δὲ τῆς ὄψεως τεφρώδης, καὶ κοιλάδας φαίνει σηραγγώδεις πετρῶν αἰθαλωδῶν κατὰ τὴν χρόαν, ὡς ἂν ἐκβεβρωμένων ὑπὸ πυρός· ὡς τεκμαίροιτ' ἄν τις τὸ χωρίον τοῦτο, καίεσθαι πρότερον, καὶ ἔχειν κρατῆρας πυρός, σβεσθῆναι δ' ἐπιλιπούσης τῆς ὕλης. Τάχα δὲ καὶ τῆς εὐκαρπίας τῆς κύκλῳ, τοῦτ' αἴτιον, ὥσπερ τῇ Κατάνῃ φασί, τὸ κατατεφρωθὲν μέρος ἐκ τῆς σποδοῦ τῆς ἀνενεχθείσης ὑπὸ τοῦ Αἰτναίου πυρός, εὐάμπελον τὴν γῆν ἐποίησεν.

(Rerum Geog. lib. v. cap. iv.)

DIODORUS SICULUS.

(p. 6.)

Ὠνομάσθαι δὲ καὶ τὸ πεδίον τοῦτο Φλεγραῖον, ἀπὸ τοῦ λόφου τοῦ τὸ παλαιὸν ἄπλετον πῦρ ἐκφυσῶντος, παραπλησίως τῇ κατὰ τὴν Σικελίαν Αἴτνῃ. Καλεῖται δὲ νῦν ὁ τόπος Οὐεσούσιος, ἔχων πολλὰ σημεῖα τοῦ κεκαῦσθαι κατὰ τοὺς ἀρχαίους χρόνους.

(Lib. iv. cap. 21.)

C. VELLEIUS PATERCULUS.

(p. 6.)

C. Velleius Paterculus, a native of Campania, has these words in the Second Book :—

'Dum Sertorianum bellum in Hispaniâ geretur, LXIV fugitivi e ludo gladiatorio Capuâ fugientes, duce Spartaco, raptis ex eâ urbe gladiis, primo Vesuvium montem petiere, mox crescente in dies multitudine gravibus variisque casibus affecêre Italiam, quorum numerus in tantum adolevit ut, quâ ultimo dimicavêre acie $\overline{\text{XLM}}$ hominum se Romano exercitui opposuerint. Hujus patrati gloria penes M. Crassum fuit mox Romanorum omnium principem.'

PLUTARCH.

(p. 7.)

Plutarch (iii. 426. 9) is referred to for an amplified account of the escape of Spartacus from Vesuvius :—

Καὶ πρῶτον μὲν τοὺς ἐκ Καπύης ἐλθόντας ὠσάμενοι, καὶ πολλῶν ὅπλων ἐπιλαβόμενοι πολεμιστηρίων, ἄσμενοι ταῦτα μετελάμβανον,

ἀπορρίψαντες, ὡς ἄτιμα καὶ βάρβαρα, τὰ τῶν μονομάχων. Ἔπειτα Κλωδίου στρατηγοῦ μετὰ τρισχιλίων πεμφθέντος ἐκ Ῥώμης, καὶ πολιορκοῦντος αὐτοὺς ἐν ὄρει μίαν ἔχοντι καὶ χαλεπὴν καὶ στενὴν ἄνοδον, ἣν ὁ Κλώδιος ἐφρούρει, τὰ δ' ἄλλα κρημνοὺς ἀποτόμους καὶ λισσάδας, ἄμπελον δὲ πολλὴν ἀγρίαν ἐπιπολῆς πεφυκυῖαν, ἔτεμνον τῶν κλημάτων τὰ χρήσιμα· καὶ συμπλέκοντες ἐξ αὐτῶν κλιμακίδας εὐτόνους καὶ βαθείας, ὥστ' ἄνωθεν ἀνηρτημένας παρὰ τὸ κρημνῶδες ἅπτεσθαι τῶν ἐπιπέδων, κατέβαινον ἀσφαλῶς δι' αὐτῶν, πλὴν ἑνός. Οὗτος δὲ τῶν ὅπλων ἕνεκα μείνας, ἐπεὶ κατέβησαν, ἠφίει κάτω τὰ ὅπλα, καὶ βαλὼν ἅπαντα, τελευταῖος ἀπεσώζετο καὶ αὐτός. Ταῦτ' ἠγνόουν οἱ Ῥωμαῖοι· δι' ὃ καὶ περιελθόντες αὐτοὺς, ἐξέπληξαν τῷ αἰφνιδίῳ, καὶ φυγῆς γενομένης, ἔλαβον τὸ στρατόπεδον.

NERO.

(pp. 12, 216, 228.)

In his Life of Nero (cap. 31), Suetonius narrates many extravagant fancies and enterprises of that fastidious ruler of the world. His schemes relating to the region we are considering run thus :—

'Præterea inchoabat piscinam a Miseno ad Avernum lacum, contectam, porticibus conclusam, quo quidquid totis Baiis calidarum esset converteretur. Fossam ab Averno Ostiam usque, ut navibus, nec tamen mari, iretur, longitudinis per centum sexaginta milliaria; latitudinis qua contrariæ quinqueremes commearent. Quorum operum perficiendorum gratia, quot ubique essent custodiæ, in Italiam deportari, etiam scelere convictos non nisi ad opus damnari, præceperat.'

And he was sustained in his mad projects by the hope of discovering enormous treasures which Dido, when she fled from Tyre, had concealed in vast caverns in Africa.

POZZOLANA.

(pp. 38, 135.)

Vitruvius (lib. ii. cap. vi.) gives an account of the volcanic sands, in the fashion of an architect:—

'*De pulvere Puteolano.*

'Est enim genus pulveris, quod efficit naturaliter res admirandas. Nascitur in regionibus Baïanis, et in agris municipiorum, quæ sunt circa Vesuvium montem, quod commixtum cum calce et cæmento non modo cæteris ædificiis præstat firmitate, sed etiam moles quæ construuntur in mari, sub aqua solidescunt. Hoc autem fieri hac ratione videtur, quod sub his montibus et terra ferventes sunt fontes crebri, qui non essent si non in imo haberent, aut de sulfure, aut alumine, aut bitumine ardentes maximos ignes: igitur penitus ignis, et flammæ vapor per intervenia permanans et ardens, efficit levem eam terram, et ibi, qui nascitur tophus, exiguus est, et sine liquore. Ergo cum tres res consimili ratione, ignis vehementia formatæ in unam pervenerint mixtionem, repente recepto liquore una cohærescunt, et celeriter humore duratæ solidantur, neque eas fluctus, neque vis aquæ potest dissolvere.'

Seneca, Nat. Quæst. iii. 20, says of pulvis Puteolanus, 'si aquam adtigit, saxum est.'

And Pliny, H. N. xxxv. 45. in § 13, 'Quis enim satis miretur pulverem appellatum in Puteolanis collibus, opponi maris fluctibus, mersumque protinus fieri lapidem unum inexpugnabilem undis, et fortiorem quotidie utique si Cumano misceatur cæmento.'

These passages explain the watery solidification of the ashes of the volcanos.

Scipione Falcone, in his Discorso Naturale delli Cause et Effetti del Vesuvio, says that he saw, after the eruption in 1631 (which was attended with hot water), the mud harden almost to a stone in a few days. His words are these :—

'Fatta dura a modo di calcina e di pietra non altrimenti di cenerè, perchè dopò alcuni giorni vi ci e caminato per sopra e si è conosciuta durissima che ci vogliano li picconi per romperla.'

REV. JOHN MITÇHELL.

(p. 254.)

To the brief account of this remarkable hypothesis it may be added, that the fluid over which the crust of the earth is supposed to undulate, is not lava, but vapour generated on the access of water to an incandescent stratum, which is interposed among other strata of ordinary character. The vapour-wave makes broad undulations, and moves between the layers of rock, faster than the tremors which vibrate through them ; and still faster than the water-waves which are often generated in earthquakes. The view of Professor Rogers is that the undulations are in the lava.

PRINCIPAL FORBES.

(p. 328.)

The following instructive letter of Principal Forbes is referred to :—

St. Andrews,
Nov. 19, 1866.

My dear Phillips,

I am glad that you directed my attention by a recent letter to the amount of the flux of heat through the earth's

crust, because it has recalled to my recollection a correspondence which I had in the latter part of 1861 with Professor (Sir) William Thomson, and to some calculations I then made on the subject.

You will find numbers deduced by Thomson for the conductivity of the three kinds of rocks near Edinburgh on which my observations were made, as follows :—

		Trap.	Sand.	Sandstone.
K	=	124·2	78·31	319·3

(the Cent. degree, French foot, and the year being units.) These slightly differ from, and are undoubtedly more accurate than, my earlier determinations.

These numbers express the number of Cent. degrees by which in each case a cubic foot of water would be heated in the lapse of 1 year, by the heat conducted through a layer of each rock 1 French foot thick, with its surfaces maintained constantly at temperatures differing by 1° Cent.

But in the actual condition of the globe I assume that the temperature increases by 1° Cent. for 100 French feet of descent. Thus the two surfaces of a layer 1 foot thick differ by but 0·01° Cent. The flux is therefore 100 times less than the above, and will raise 1 cubic foot of water in each of the above cases by

Trap.	Sand.	Sandstone.
1·24°	0·78°	3·19°

Taking the latent heat of water at 79·25° Cent., this flux of heat would melt a plate of ice whose thickness is $\frac{124}{7925}$, $\frac{78}{7925}$, $\frac{319}{7925}$ French feet, or 0·0156, 0·0098, 0·0403 feet, being respectively $\frac{1}{64}$, $\frac{1}{102}$, $\frac{1}{25}$ of a French foot.

I shall be very glad if you will publish these results, which I copy from my letter to W. Thomson, dated Dec. 13, 1861), as I believe them to be far more accurate than any which have yet been given.

I may add that you will find Thomson's recalculation of my observations and deductions therefrom in the Edinburgh Royal Society's Transactions, vol. xxii. p. 405.

Believe me, yours very sincerely,

JAMES D. FORBES.

Professor Phillips, Museum, Oxford.

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